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CONQUEST OF THE POLE

By I. D. PAPANIN

Last year, on May 21, the world was astounded by the sensational news that a Soviet flying machine, pilotted by M. V. Vodopyanov, titled Hero of the Soviet Union, had landed at the North Pole.

Everybody remembers those marvellous joyous days when the representatives of the heroic Soviet people added one more triumph to the many achieved by the Soviet Union. Following the will of the Communist Party, of the government and of Comrade Stalin personally, Soviet flyers, air navigators, mechanics and scientists have brilliantly accomplished one of the most difficult flights from the Soviet capital to the top of the world.

This victory was not a mere turn of good luck. It was the outcome of careful, preliminary painstaking work which foresaw and provided for all contingencies and soberly gauged all the caprices of nature. It was also due to the well chosen team of people, to their sterling qualities, courage, daring and ability and to their boundless devotion to the cause of Lenin and Stalin.

Those who, upon waking up in the morning of May 22, learnt from the newspapers about the incredibly daring leap of Vodopyanov, naturally had no inkling of the enormous preparatory work that preceded this triumph. Scores of plants, scores of organizations lent a hand in this work; some of them were building the flying machines, others were rigging them out, others again were engaged in manufacturing the equipment, some were manufacturing scientific instruments for the drifting station and others were providing the food supplies. The expedition was fully armed with technical and scientific means for its attack on the Pole. The following fact will give an idea of the scale on which these preparations were made. On Rudolf Island, one of the remotest of the islands of Franz Josef Land, a powerful auxiliary base was fitted out in 1936 for the purpose of facilitating the task of the expedition.

The object of our flight was not merely to reach the North Pole. People have been at the Pole before us, but their visit to the Pole contributed nothing to science, either pure or applied. Soviet explorers in their offensive against the Arctic were moving forward gradually. Every year took them farther and farther in their inroads into the North. The time arrived when it became essential for us to get information from the Central Arctic regions and we

could not get on without the North Pole. Then it was decided that the North Pole was not only to be reached, but was to be made to serve the cause of science and progress.

We were confronted with difficulties and obstacles. But the main difficulty was not the severity of the Arctic regions; however high the ice barrier of the unknown latitudes was, it was not so high as the barrier of conservative ideas raised by bourgeois science. The conviction prevailed that it was impossible for flying machines to land on the ice-fields of the North Pole. There was the traditional idea that the Pole was a dead wilderness where there were no animals, no birds; that no living organisms were to be found in the Ocean in those regions and therefore there would be nothing for a scientist to do at the Pole.

Bourgeois science reconciled itself to the top of the world forming a blank on the map. It regarded as lunatics those who made an attempt to proceed to these regions for the purpose of scientific study rather than record breaking.

However, we have not stopped before the barrier of scientific traditions. We knew that the old traditions were masking the senile impotence of official science.

On the eve of the anniversary of the expedition to the North Pole we were deeply moved to hear the appraisal of our work from the mouth of Comrade Stalin, the greatest man of our times. In his remarkable speech delivered at the reception given in the Kremlin to the workers of higher education on May 17,1938, Comrade Stalin said that owing to our practical work on the drifting ice-floe the former idea of the Arctic regions became at once obsolete and a new one has been established which is in accord with the demands of a real science.

We proceeded to the North Pole with the feeling of confidence which the Party of Lenin and Stalin instilled into us. We were sure of our forces and we knew that the whole of our country was backing us. Everything was of interest to us. We wished to discover the laws governing the drifting of the ice in the central Polar basin, to study the currents and waters of the central part of the Arctic Ocean, to investigate the biological life of the regions near the Pole, to form a clear idea of the meteorological processes to be observed at the top of the world, to make observations of terrestrial magnetism, gravitation and so on over a lengthy period of time.

Upon reaching the Pole the Soviet flying machines were to land a fully equipped scientific research station which was fit to give an answer to all these questions provided a sufficiently long period of time was spent on the ice-floe and devoted to scientific study. As we know this scheme was carried out in full. The flying expedition and the scientific station have solved the problems set before them; the traditional idea that the Polar region is inaccessible and devoid of all life has been exploded. World science will receive from the hands of Soviet scientists and Soviet flyers complete and exhaustive data on the physical and chemical processes that are taking place in the centre of the Arctic Ocean.

ARCTIC
OCEAN
North Pole
GREENLAND
Drift of the North Pole Station
Rudolf-Island
Franz-Josef-Land
Spitzbergen
Novaya Zemlya
KARA SEA
BARENTZ SEA
GREENLAND SEA
NORWEGIAN SEA
Island
SCANDINAVIA
MOSCOW
SCALE
250 0 250 500 750 1000 km

Although the flying expedition was only a part of the whole undertaking, its name was justly inscribed in the history of the greatest feats of human daring. The wounderfully graceful flight of a powerful squadron of Soviet airplanes, which confidently traced its way from Moscow to the North Pole and returned in perfect order to the beloved capital, will always remain fresh in the memory of our contemporaries.

Now, recalling the days of that heroic epic, we feel proud to have taken part in it. The plan for storming the Pole was mapped out as thoroughly as the plan of the expedition. We shall recall this plan in its main outline. We took off from Rudolf Island on May 21, and reached the Pole a few hours later. The Pole was utterly hidden behind a blanket of clouds. Vodopyanov on his flying machine broke through these clouds and having chosen an ice-floe made a most successful landing upon it. We maintained regular contact by radio with the other three flying machines of the expedition which were stationed on Rudolf Island. The flying machines of the second detachment started for the North Pole on the night of May 25. One may imagine how difficult it was to find our little camp in the endless wilderness of ice. Nevertheless Molokov with his amazing navigator Alexis Ritsland came to our ice-floe having drawn a bee-line in the air. Alexeyev and Mazuruk with their planes landed in the region of the Pole and soon joined us.

A settlement grew up at the North Pole; it consisted of thirty five Soviet citizens. The flying machines brought us various instruments, equipment and food. Our friends spent sixteen days with us assisting us in the work of installing our drifting station and landing us a hand in our first scientific observations.

The work of the flying expedition headed by O. J. Schmidt, titled Hero of the Soviet Union, was concluded as successfully as it was begun. This was quite natural since the Soviet government, which spares no means in developing science, did all that was necessary to secure the success of the expedition. It placed at the disposal of the Northern Sea Route Administration millions of money and the best, most up-to-date planes. Could we fail to win under these conditions?

The members of the expedition who returned by boat arrived at Moscow on June 25 and were given a great reception by the people, by Comrade Stalin and his closest colleagues. The first part of the task set by the Communist Party and the Soviet government was accomplished; in fêting the members of the expedition the country gave honour where honour was due. Four men remained on the ice-floe at the North Pole: Krenkel, Shirshov, Fedorov and myself. It was our duty to accomplish the second part of the task of the expedition, namely, to make an exhaustive study of all the processes taking place in the centre of the Polar basin.

Our group which remained at the Pole was working calmly and confidently being conscious of the support of the great Soviet people, of the care and attention of the government and of Comrade Stalin. We were aware that the progress of our work was being followed, and that no amount of effort and means would be spared in our behalf in case of need. And when

our ice-floe had split into small tumbling pieces we remained calm preserving our high Soviet spirits; we were firmly confident that the country, the Communist Party and Comrade Stalin would not let Soviet people perish.

The flight to the North Pole has demonstrated to the whole world the power and might of Soviet aviation whose opportunities are illimitable. This flight practically served as the beginning of the organization of a transarctic air route between the two continents. And one month later, in June 1937, Comrades Chkalov, Baidukov and Belyakov, titled Heroes of the Soviet Union, were given permission by the government to start on their flight from Moscow to North America. This flight turned out a brilliant success. Some time later Comrades Gromov, Yumashev and Danilin, titled Heroes of the Soviet Union, made their flight along the same route and broke all world records of long distance flight; they at the same time proved the practicability of this route.

The flight of the airplanes of Schmidt's expedition and of those pilotted by Chkalov and Gromov made it obvious that air navigation in the central Polar basin was feasible even at the present stage of aviation technique. The problem of a transarctic air route which so long occupied the minds of flyers of all countries was fundamentally solved. It has been shown that the aeronavigational difficulties peculiar to the region lying near the Pole could be surmounted. It became evident that the severe meteorological conditions, particularly capricious and changeable in the Arctic regions, could likewise be overcome.

Needless to say the practical organization of an air route over the North Pole connecting the two continents will require a good deal of further effort and means. It will be necessary to continue the careful study of the central Arctic regions and set up along the proposed route auxiliary bases similar to the one on Rudolf Island.

The press of the world devoted exceptionally great attention to the work of the expedition last year. The press regarded this work as one of the most remarkable victories of human genius in recent times. The work of the four of us was not less highly praised. The papers still continue to write of the Soviet people who gained the mastery of the North Pole. Naturally not all of them give an objective appraisal of the progress and results of the expedition. Only a few organs of the bourgeois press were able to discern behind the individual heroism the collective body which was closely connected with the people, feeled itself as part of the people and was always conscious of the powerful support of the people.

The London Observer, quite recently, on April 10 of the current year wrote somewhat confusedly:

«Those Russians, the whole crew of them, were remarkable men, courageous, prudent, cheerful; and each had a degree of technical accomplishment as a navigator or an engineer which critics who doubt them had better carefully note. Their friendliness is apparent, but though lighthearted they are most formidable. They made no mistakes, in circumstances bad enough to give an ordinary hero the shivers. But these Russians had complete confidence

in the soundness of their equipment and organization, which had been perfected after years of experiment. They had earned the right to sing the «International» while standing over the axis of the earth».

We love our joyous happy life which the great Stalin gave us and are ready to fight and die for it. We want to live, to do some creative work, to work in all the spheres of socialist construction, we want to live to beat the enemies, we want to live in order to win!

Our people is solidly united round the Party of Lenin and Stalin, around the beloved Comrade Stalin; with iron step it marches towards new victories of Socialism. Having crushed all and every enemy within the country, having crushed all the trotskyite-bukharinite fascist reptiles, our people has closed its ranks still more tightly round the Communist Party, round the Soviet government. The Soviet people demonstrated on December 12, the day of the elections to the Supreme Council of the USSR, that it was a united people. The working people of the Soviet Union will once more demonstrate in the coming elections to the supreme councils of the Union republics that they are morally and politically united.

And should the enemy dare to step on Soviet soil, should he dare to aim a blow at our happiness, he would be sure to break his head against the invincible wall of patriots of the socialist country.

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OCEANOLOGY

OCEANOLOGICAL OBSERVATIONS

By P. P. SHIRSHOV

(Communicated by O. J. Schmidt, Member of the Academy, 8.V.1938)

DEEP SOUNDINGS

1. Depths Searched out in the Polar Basin. The last bathymetrical chart of Nansen shows 17 deep-sea soundings, exceeding 2000 m, taken in the Polar basin. Besides, there are 7 soundings, where the ocean bottom was not reached. Of these soundings nine were taken by the «Fram» expedition (as well as 10 «stray-soundings», i. e. soundings which missed the bottom). One station was taken by the «Sadko» expedition in 1935. Five stations and 3 «stray-soundings» were taken in the Beaufort Sea. The aforesaid total of 17 soundings includes 2 soundings taken by means of sounding-lead: by Wilkins at a depth of 5440 m and by Risser-Larsen at a depth of 3750 m. The latter two measurements give rise to doubt, particularly Risser-Larsen's station, which is situated in the area where our stations, taken by means of a hand-gear, reached depths over 4200 m. Thus, until recent times there were altogether 15 reliable stations taken along the edge of the basin.

Our expedition carried out a total of 33 soundings, of which 15 were taken at a depth of more than 2000 m.

2. Methods of Soundings. The expedition was equipped for deep-sea soundings with a specially designed windlass of about 60 kg weight; the windlass together with the wire-rope weighed about 110 kg. The windlass was fitted with an automatic brake of the «Lucas» type, stopping the reel of the windlass at the very instant the weight striked the bottom.

Gomoiunov's rod, weighing 26 kg, was used as plummet. The rod was fitted with a metallic tube for taking samples of the bottom ground. The line, 1.25 mm in diameter, was made of seven galvanized steel wires twisted together. At each sounding a bathometer was attached above the weight for taking a sample of the bottom water. By means of the rod, we succeeded in taking seven samples of the bottom ground in the central part of the ocean. At the eighth sounding the rod tore off. An attempt to work with a tube for taking ground also ended in tearing of the line.

3. Results of Soundings. Soundings which were taken beginning from 89°, at 30-mile intervals, have enabled us to draw the profile of the ocean floor from 89° to the southern part of the Greenland Sea. The absence of land in the region of the pole was definitely ascertained. As our soundings have shown, the depth of the ocean floor near the pole reaches 4290 m. The whole area between the pole and 86° represents a deep depression with a sloping floor, with a maximum depth of 4395 m. South of 86° the ocean floor rises by leaps. The depths in this section vary from 3677 to 4050 m, and again down to 3500 m. At 84° a submarine peak was discovered, where the depth was 2380 m only. Farther south the depths are again increasing, and near Greenland (82°53′ N. lat., 6° W. long.) they suddenly attain considerable magnitude—over 4160 m*. The reason why the existence of great depths near Greenland is of interest, is that depths of the continental shelf were usually supposed there. Thus, for example, at a distance of 40 miles from the North-Eastern Cape a depth of 3372 m was met, whereas, judging from Nansen's bathymetrical chart, depths from 200 to 400 m were assumed to exist in that place. The results of the soundings in the area of the so-called «Nansen Ridge» are of particular interest. It has been known that between Greenland and Spitzbergen there was supposed a ridge with depths of 600—800 m. Except Nansen's chart the depth of the ridge in the middle part was supposed to exceed about 1000 m. The discovery of a 1420 m depth in the direct proximity of Greenland leads to the assertion that the depth of the «Nansen Ridge» is considerably greater and apparently reaches 2000 m in the middle part of the strait. In the Greenland Sea our soundings embraced the region of the least explored continental shelf.

OCEAN GROUNDS

Ground samples, taken at our northern stations in the Polar basin at depths of no less than 3767 m, represent deep water muds of three types: brown mud, grey mud and brown or pinkish sandy mud. The mechanical analysis of muds, made by T. I. Gorshkova, showed the following varieties of muds:

The Mechanical Composition of Grounds (in %)

Fraction (mm)	1.0— 0.1 (rhizopods)	0.1— 0.05	0.05—0.01	0.01
Brown	1.1— 1.7	21.3—28.1	22.6 —33.6	40.9—50.9
Grey	Traces	6.3— 9.7	41.5 —52.8	40.9—48.8
Sandy	1.3—12.0	29.0—34.3	31.6 —42.2	22.1—28.9

The fraction 1.0—0.1 is represented almost entirely by calcareous rhizopods.

In the distribution of muds the following peculiarities may be noted: the sloping bottom of the deep depression between 89 and 86° is covered with two layers of mud—the upper brown and the underlying grey mud. The

* At the preceding station 500 m of line tore off and only 4200 m were left on the reel of the windlass; that appeared to be insufficient for measuring the depth at this point.

brown mud contains a considerable amount of rhizopods, of which there are practically none in the grey mud. According to the mechanical composition, the grey mud is the finest; more than 90% of the latter is composed of fractions smaller than 0.05 mm. As to the brown mud, from 20 to 28% of it is made up of large fractions 0.1—0.05 mm. The ocean bottom rising unevenly to the south of 86° is carpeted with sandy mud of brown or pinkish colour. Unlike the former two types of mud, the composition of the sandy mud is such that fractions smaller than 0.01 mm constitute no more than 29%. However, in some of the samples the 1.0—0.1 fraction constitutes 12%, and is almost entirely made up of rhizopods. Thus, the increase of the amount of rhizopods in the southern region of the Polar basin is distinctly emphasized. This seems to be closely connected with the rise of temperatures in the Atlantic water layer, which became manifest as we were moving southward.

HYDROLOGICAL REGIME

Beginning from 89°, deep hydrological stations were taken at 30-mile intervals, and in many cases even at closer distances. From 89 to 76° altogether 38 stations were taken. At each station temperatures were measured and samples for the determination of salinity were taken at usual hydrological horizons. In view of the fact that in the process of work small bathometers (300 cm^3 in volume) proved to be unreliable, large bathometers (volume—1 litre) were used for taking samples and were sunk in series of 3—4 bathometers. The water samples for the determination of salinity were titrated in the tent in a field laboratory. 680 soundings were taken in all.

The upper strata from the surface down to a depth of 200—250 m consist of waters of low salinities and negative temperatures, which are usual in Polar seas.

The salinity of water at a depth of 5 m (i. e. 1½—2 m beneath the ice surface) during the summer months, i. e. in the period of intensive ice melting, fluctuated from 29.52 to 29.81‰. With the cessation of ice melting, the salinity of the upper layer increased from 31.00 to 31.60‰. The temperature was at its lowest at the depth of 50—75 m and reached in high latitudes—1.70—1.77°.

The depths from 200—250 m to 750—800 m are filled with water of Atlantic origin with high salinity and positive temperatures. At northerly stations the thickness of the Atlantic water layer reaches 500 m. Approximately at the depth of 250 m the upper zero isotherm may be drawn. The lower zero isotherm is found at a depth of 750 m. The maximum temperature of Atlantic water at northern stations is +0.79° at a depth of 400 m. The salinity of the water of the Atlantic layer has a rather constant value of 34.94—34.96‰. As it drifts southward, the thickness of the Atlantic water layer with positive temperatures increases considerably, and in latitude 83°30′ reaches 600 m. The temperature of the water increases too. At 82° N. lat. the maximum temperature of the Atlantic water in the Polar basin in our cross-section attains +1.71° at a depth of 300 m. The salinity of the Atlantic water layer remains unchanged throughout the regime. The water

layer with positive temperatures is underlain by water with temperatures gradually diminishing down to—0.83—0.86° at a depth of 2500—3000 m. The bottom layers show an increase of temperature, thus, for instance, in the central part of the basin the temperature of the bottom layer is—0.63° (at a depth of 4395 m). The rise of temperature in bottom layers, which as a rule may be observed in deep oceanic depression, is due both to the heat evolved in the processes of disintegration of organic remains, and to that supplied by the earth crust. Curiously enough in the Greenland depression a considerably lesser rise of the water temperatures was recorded at the same depths. This is apparently due to the younger age of the bottom water in the Greenland depression. The warm water, cooled in the upper layers, sinks deep down along the continental slope, and here, in the direct vicinity of the coast, it has not had the time yet to warm up to such a degree, as is observed in the central part of the basin.

During his drift in the «Fram» Nansen observed at a depth of 200 to 700—800 m water of Atlantic origin with positive temperatures and high salinity. In 1935 the «Sadko» expedition set out to the north-west of the North Land, onto great depths, and they also revealed Atlantic water at a depth of 150 to 750 m. The maximum temperature of 2.68° was recorded at a depth of 300 m. In the same year, 1935, the «Krasin» expedition found an increase of temperature and salinity of the water of the bottom layer, north of Herald Island, at a depth of 140—150 m. These observations led to the conclusion that the Atlantic waters, flowing into the Polar basin from the northern part of the Greenland Sea, curve round Spitzbergen, and pass eastward, deep too, along the northern slope of the Eurasian continental shelf. Moving in this direction, the Atlantic waters reach the Northern outskirts of the Chukotsk Sea, detaching in their course branches into the Kara and Laptev Seas. Our observations have shown that the Atlantic waters move not only eastward, but are expanding in the central part of and possibly allover the Polar basin.

The Soviet expeditions of recent years («Perseus», «Sadko» and «Sedov») yielded interesting results. The comparison of station 99 of the «Sadko» expedition in 1935, taken at the coordinates 82°42′ N. lat. and 87°03′ E. long., with station 22, taken by the «Fram» expedition (84°31′ N. lat., 85° E. long.), showed a considerable increase of the water temperature. The layer of Atlantic water at «Fram» station 22 was 600 m thick with a maximum temperature of 1.1° at a depth of 300 m. At the station 99, taken by the «Sadko» expedition, the thickness of Atlantic water layer attained 700 m with a maximum temperature of 2.6° at the same depth of 300 m. The comparison of hydrological observations of the «Sedov» expedition of 1934 with the «Sadko» expedition of 1935 and of 1936, carried out in the western gully of the Kara Sea, have shown that the temperature of Atlantic waters, which flow deep in this region, keeps on rising. In the Greenland Sea at the parallel 78 the temperature of the Atlantic water in 1935 was, according to the data of the «Sadko» expedition, by 0.5° higher than in 1933 after the observations of «Perseus». The reason for this, as shown by V. Berezkin, is the increase of

the inflow of Atlantic waters into the Polar basin, in connection with the increase of atmospheric circulation over the northern hemisphere. It is therefore of interest to compare our observations with those made by the nearest station of «Fram». At closest distance to each other are located our station 22 (83°49′ N. lat., 2°22′ E. long.) and the «Fram» station 26 (84° 06′ N. lat., 12°26′ E. long.) taken on April 15, 1896. The temperature of water at the «Fram» station 26 is at all levels higher than at our station 22 at respective levels. Unfortunately, at this station there were no temperature measurements taken by Nansen at depths of 300 and 400 m, at which he had usually observed a maximum temperature. Later on from indirect data he estimated the temperature at a depth of 400 m as being equal to 1.2°. Yet, his station was situated 70 miles east of station 22, and as it appears from the comparison of our stations 22 and 23 (the coordinates of the latter are 83°56′ N. lat., 0° 47′ E. long.), the isotherms in this section turn quite sharply from east to west. Therefrom it may be deduced that in 1937 at the place of the «Fram» station 26 the temperature of the water was correspondingly higher than at the station 22. However, even in that case, a considerable rise of temperature in 1937, as compared to 1896, could hardly be expected. Therefore, it is not a question of Atlantic waters having grown warmer in this region. Apparently, the region of our drift, unlike the regions contiguous to the Eurasian continental slope, is in a state of greater stability, and the increase of the inflow of Atlantic waters here is of small importance. The main stream of Atlantic waters, turning quite rapidly around Spitzbergen from the north-west, rushes along the continental slope of Eurasia. In the central part of the Polar basin Atlantic waters seem to move rather slowly. Yet, it will be possible to answer this question only after a due treatment of the materials collected, particularly after an analysis of the hydrological observartions and their comparison with materials of other expeditions.

CURRENT-METER OBSERVATIONS ON THE DRIFT AND ON SURFACE CURRENTS

Observations on the Drift. In order to complete the detailed chart of the drift, current-meter observations were taken on the velocity and trend of the drift. The observations were carried out by means of an Ekman-Mertz current-meter sunk to a depth where the current velocity might be assumed to be zero. Originally a depth of 1000 m was held as a limit, where the water could be considered stagnant. Yet, later on by comparing the readings of two current-meters, sunk simultaneously*, one to a depth of 1000 m and the other to a smaller depth (300—400 m), we found it possible to confine ourselves to a depth of 300—400 m, since at such a depth the current velocity is practically zero (within experimental accuracy). Observations have been carried out 5—6 times a day for a period of three summer months.

* One of the available current-meters had been remodelled in the workshop of the All-Union Arctic Institute in such a way, as to make it fit to be attached to any point of the line.

The results of the current-meter observations showed that the course of the ice-floe was much more sinuous that it was believed on the ground of astronomical determinations. We succeeded in recording a number of small loops in the course of the drift, 1—2 km in diameter, which had escaped the astronomical observations. Particularly, we were able to trace the changes in the direction of the drift of the ice-floe following the alterations of the direction of the wind. In those cases when the wind blew from the north or the west, the drifting ice-floe changed its course very rapidly, so that it lite-

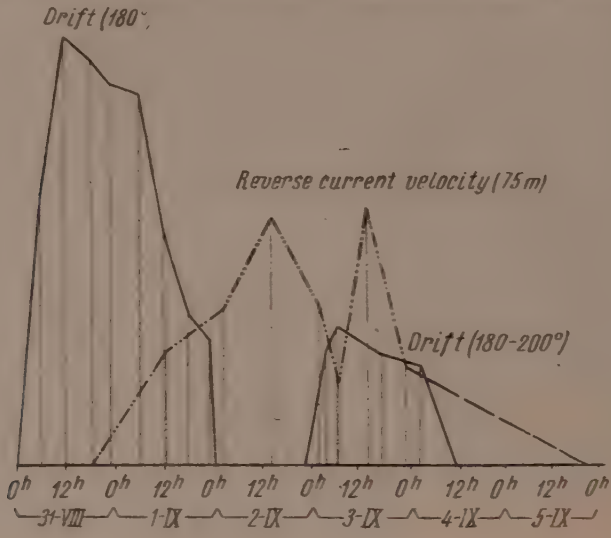

Fig. 1.

rally followed every turn of the wind. But when the wind began to blow from the south or the east, the drift of the ice-floe changed direction «very reluctantly», and it took a few hours of persistent wind for the ice-floe to turn northward or westward. It should further be noted that eastern winds caused quite intensive hummocking along the border of our ice-field. The reason lay in the fact that whenever the drift turned northward or westward, it met the resistance of the ice drifting from north to the south at some distance from the station.

Observations on Currents in the Upper Strata of the Sea. Owing to friction, the ice while moving on the surface of the sea, engages the water of the upper layers in motion. However, the velocity of the current produced by the drift of the ice diminishes very rapidly with depth. Whereas at the depth of 5 m, i. e. 1—2 m beneath the ice surface, the velocity of the drift water current reached 90—100% of the velocity of the ice-drift, at the depth of 25 m the current velocity did not exceed 20—30% of the velocity of the ice-drift.

It is noteworthy that owing to the deflecting force of the earth's rotation (the effect of the Coriolis force), the current in the upper layer deviates to

the right of the direction of the ice-drift. At a depth of 25 m the angle of deviation equals 20—30°.

The drift current is very unstable. It arises a little while after the outset of the drift, but ceases just as quickly as soon as the drift stops. After the termination of the drift no remaining drift currents were observed.

The current-meter observation enabled us to discover and then to trace the counter-currents resulting at a certain depth after a prolonged drift. A swift drift, carrying off the water of the upper layer, drives it away from the given region. It is replaced by waters from the adjoining regions, first of all from the region the drift is moving to. Thus, a counter-current arises

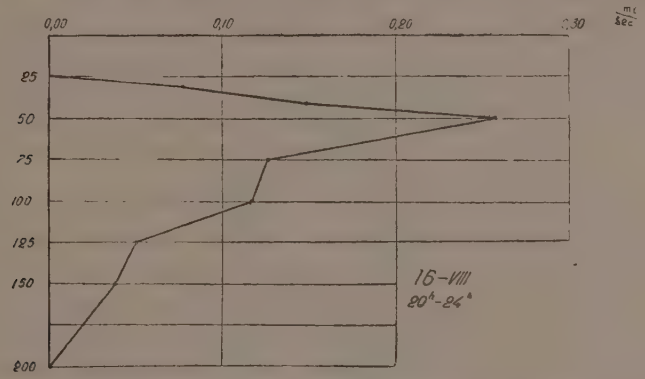

Fig. 2. Reverse current velocity according to depths.

compensating the water driven away from the given region. The counter-current was observed at some depth under the upper most layer, more frequently at a depth of 50—75 m. In cases of prolonged and rapid drifting the counter-current sweeps a thicker layer, sometimes the entire mass of water down to the eddy viscosity limit, i. e. to the depth of 150 m, in other words, to the boundary zone between the freshened sufface water and the underlying Atlantic saline water.

Unlike the drift currents of the upper layer, the counter-current does not immediately follow the beginning of the drift, but starts after a certain delay, from 12 to 36 hours after the beginning of the drift. Accordingly the counter-current is characterized by a greater stability—it lasted usually quite a long time, not infrequently several days after the cessation of the drift it was produced by. Thus, for example, after the rapid drift of August 10—13, the counter-current was observed until August 19, i. e. 5 days after the cessation of the drift.

HYDROBIOLOGICAL OBSERVATIONS

M e t h o d s. Plankton samples were taken by stratified hauls with plankton nets from various depths down to 3000 m. Zooplankton was hauled with a net of silk № 3, and phytoplankton with a net of silk № 25. For the capture of zooplankton an ordinary (standard) net «Jeddy» and for phyto-

plankton a smaller net «Jeddy» were used. The samples were sifted through the net № 25 and the derived sediment was placed into small test-tubes filled with alcohol. The amount of phytoplankton was determined after the amount of chlorophyll contained in the cells of algae. The amount of chlorophyll in the alcohol extract of plankton was determined by the spectrocolorimetric method, by way of comparison with a standard solution of chlorophyll.

Specific Composition of Zooplankton. B. G. Bogorov has made a preliminary examination of the plankton samples taken at the northern stations between 89° and 87°30′. As a result, a great variety of species has been noted, of *Copepoda* in particular, and especially in hauls from the surface down to a depth of 1000 m. For instance, at the station 2 in the sample taken on July 11, from a depth of 1000 m up to 3 m the following forms have been found: *Spinocalanus longicornis, Metridia longa, Calanus hyperboreus, Calanus finmarchicus, Microcalanus pygmaeus, Pseudocalanus* sp., *Euchaeta norvegica, Heterochaeta norvegica, Scaphocalanus acrocephalus, Mormonilla polaris, Oithona similis.*

Apart from this, there were about 10 species of *Copepoda* contained in that sample, which remain as yet undetermined, since many of them were young and can be determined only after the complete treatment of samples, collected at other stations, when the species to which these stages belong will have been identified. Such a great variety of species is the outstanding feature of these stations, and perhaps of the whole Polar basin in the Polar region. In the Greenland Sea, in the Barentz and Kara Seas, the number of species at a station does not exceed 10, and there are usually 5—6 species of *Copepoda*. Whether separate species are to be considered new species, is thus far difficult to say; at any rate, it should be noted that a part of these species were not observed among the plankton samples gathered by the «Fram» expedition. This may be seen when comparing the *Copepoda* species thus far undefined with those shown in the work of Saars, composed from the materials of the «Fram» expedition. Apart from *Copepoda*, in the material available have been found *Amphipoda, Pseudolibratus* and *Cyclocaris* Guillemi; *Radiolaria* (2 types); *Kronia*; *Ostracoda—Conxaecia maxima*; of the *Appendicularia—Tritillaria*; siphonophoran *Dyphies.*

The Vertical Distribution of Zooplankton. The richest are the upper layers (samples were taken from depths 3—250 m and 3—1000 m). Below 1000 m scantiness begins, especially manifest from a depth of 2000 m and down. There is a decrease in the variety of species and the number of specimens. In deep strata of 2000 to 3000 m, there is a relative increase in the amount of *Oncea* and *Conxaecia* which are comparatively scarce in layers above 1000 m. In these abyssal layers characteristic inhabitants of the Greenland Sea and the North Atlantic *(Calanus finmarchicus, Euchaeta norvegica)* have not been found yet. In layers above 100 m there is an abundance of the usual population of the Northern Atlantic regions: *Calanus finmarchicus, Microcalanus pygmaeus, Euchaeta norvegica, Oithona similis, Metridia longa, Pseudocalanus.*

The remaining species are typical representatives of the fauna of the Polar basin and the northern parts of the Greenland, Barentz and Kara Seas.

Thus, the examination of the plankton samples fully confirms the Atlantic origin of the waters with positive temperatures, found at depths of 250 to 750 m.

Phytoplankton. The phytoplankton in the samples taken in July is poor with regard both to quality and quantity. On the other hand, in August there was an profuse assemblage of *Diatomaceae. Peridineae* are of rare occurrence. However, even in August the specific composition of the phytoplankton is very poor. In the plankton samples lots of *Chaetoceros socialis* are met. In a number of samples are often encoutered *Chaetoceros atlanticus*, *Ch. borealis*, *Thalassiosira bioculata*, *Ch. furcellatus*, *Coseinodiscus oculus iridis*. In small quantities occur species which usually dwell in Polar seas adjoining the coast, such as: *Fragilaria oceanica*, *Thalassiosira Nordenskiöldii*, *Th. gravida*, *Nitzschia seriata*, *Achnantes taeniata*, some species *Chaetoceros*, *Pleurosigma* and others.

The considerable development of phytoplankton which was observed throughout the month of August, is interesting from a general biological viewpoint. On the basis of his investigations, Nansen arrived at a conclusion that the Polar basin is extremely poor both in vegetable and animal life. The reason for this scantiness he saw in that beneath the compact ice-cover the phytoplankton algae cannot develop on account of the absence of sunlight which is necessary for the photosynthesis. In the opinion of Nansen, the vegetable life in the Polar basin is represented almost exclusively by a limited number of diatomaceous algae, accumulating in the shape of slimy clots among the ice-floes, in the open water, during the short summer period. Nansen believed that apart from such accumulations of ice diatomaceae, vegetable organisms are almost absent in this region. Since, however, no animal life can exist without vegetable plankton, the central part of the ocean may be considered a desert in the ocean, and neither mammals nor man can find any food there.

Before we turn to our observations, we will say a few words in general about laws governing the plankton life in seas of more southerly latitudes. In seas of temperate zones the winter period is characterized by a poor plankton, especially phytoplankton. With the set in of the spring, in the upper strata of the sea begins an intensive development of phytoplankton, the so-called spring flowering. There is a second maximum of the phytoplankton observed in autumn—the autumn flowering. In the Polar seas both maximums fall within the same period, and the spring flowering is observed already in summer. In the Chukotsk Sea, for instance, it starts in July and on the Wrangel Island even as late as August. The impetus, provoking flowering in Polar seas, is the rarefaction of the ice-cover, which allows sun rays to penetrate into the upper layers of water to a degree which is sufficient for the photosynthesis.

In the region under our investigations the biological seasons succeeded each other in the following way: throughout July the plankton remained

in the state of biological winter. This was obvious from the age of the animals—in all species there prevail grown-up organisms or the highest stages of growth (IV and V). However, judging by the great number of adult females and males and the presence of a few specimens of nauplii (larvae of the *Copepoda*), one might infer that the plankton had entered the second stage of the biological winter, the pre-spring stage. The phytoplankton of the July samples was very poor. At the beginning of August the spring flowering of the diatomaceae set in, and it lasted through the whole month. Naturally enough the ice-cover did not rarefy here as it does in seas adjoining the coast. The ice remained compact throughout. Occasional water unlocked by the ice (polynyas) and cracks should not be taken into consideration. Besides, they could be observed in June and July too, when there was no flowering. But then in July the snow cover, which at the end of the winter was 40—50 cm thick, disappeared entirely. The melting of ice set in. Immense pools and lakes of melt water covered the greater part of the ice-field surface. There were no holes thawed right through the ice to be seen, but obviously the transparent ice at the bottom of such holes allowed an adequate amount of sunlight to penetrate into the upper layers of the sea. This proved to be sufficient for the development of phytoplankton at a depth of 3 to 20 m. Our observations confirmed definitely the fact that in Polar seas the absence of light under the ice-cover is the factor which prevents flowering. Not unfrequently assumptions were made that the flowering of plankton was in close dependence upon the decrease of water salinity during the melting of ice. However, in our conditions melting water stays on the very surface of sea water and contributes very little to the decrease of salinity of the underlying layers. As to the stimulating effect of the meltwater (introduction of trihydrol molecules), they do hardly penetrate in great quantity to a depth of 10—20 m where abundant planktonic development is observed; besides, melting takes place during the whole month of July, and already in July meltwater accumulates under the ice, whereas flowering starts only in August.

The amount of phytoplankton expressed in chlorophyll was found to attain 0.4 mg/m³. This is a considerably lower ratio than, for instance, in the Chukotsk Sea during spring flowering, but quite close to what has been noted in the open parts of the Laptev Sea. Anyway, it is quite sufficient for the development of zooplankton, and, consequently, of higher forms of animals.

Indeed, during the drift of high latitudes (in summer time) we saw 8 times sea gulls when they flew over open water between ice-floes. We have not succeeded in catching any sea gulls, but in all probabilily these were *Fulmarus glacialis* and *Rissa tridactyla*. Once appeared a *Cepphus mandti*. At 88° bears approached our camp—a she-bear and two cubs. A sea-hare was also met there. At 87°47′ we sighted a sea-dog *(Phoca hispyda)*. Thus, the conception that the central part of the Polar basin is a lifeless desert, is again disproved.

THE DESCRIPTION OF THE ICE-COVER

As it was known, our station was situated on an ice-field about 4 km long and up to 2 km wide. The thickness of the field in even places was 3 m. The surface of the field was smooth in the main part and looked like separate small plains of a length up to 1 km, separated by low hill-masses of old hummocks, smoothed down by snow. These hills in the midst of the ice-field were rarely more than 1 m high. Along the edges of the field in the east, south and west were hills of old hummocks, also smoothed by snow. On the southern and south-eastern side, along the border of the field, stretched low hills (1 and rarely 2 m high) in two rows. Between these rows was a sheet of fresh ice of 100 m width. The inner row was obviously the old edge of the field and the outer—the new one, formed after the space of open water (polynya) along the edge of the ice-floe had frozen over. Along the edge of the field at times slight pressure occurred, resulting in upheaval of ice masses and formation of hummocks which but seldom attained a height of 3 m. In order to study the general character of the ice-cover in the vicinity of the station we made three ski excursions in different directions, 15—18 km off the station. During our excursion in the north-eastern direction, our way led through hilly fields, entirely devoid of level space. The hills there were also smoothed down reaching a height of 3 m. The width of the neighbouring field, adjacent to ours, proved to be 6 km. Over a distance of 6 km we came to a band of pack ice, from 1 to 1½ km wide. Here were met débris of ice-fields from tens of metres to half a kilometer the size. This region is characterized by the abundance of piled up ice, of fresh hummocks. In two places 10 m high ridges of hummocks composed of small pieces of smashed ice were encountered. During the excursion in the south-western direction our way led first through a hilly rugged surface of two field 3—4 km wide, separated by a narrow crack with small hummocks. Occasionally broken slabs of ice up to 3½ m thick were met. The average height of the hills and hummocks was 1—2 m. Further lay a large smooth field, almost completely devoid of elevations, up to 5 km long. Along its edge stretched ridges of hummocks up to 1—2 m high. Alongside of this field was a second field with the same smooth surface, about 3 km the size. At a distance of 15 km from the station, we came across a wide band of pack ice. Behind that band apparently stretched large, relatively smooth fields. During our excursion in the south-eastern direction we were going 12 km over a compact field with a rather uneven surface. Now and then appeared smooth small plains, alternating with masses of hummocks crowded together. After passing this field, we met a band composed of small hummocks, débris of ice-floes and large spaces of water locked with young ice. The separate spaces newly locked measured 200—500 m. Beyond that band, our way went again along an old hilly field.

As a result of these excursions, the ice-cover in the region of the station in latitude 87—86° may be characterized in the following way. Many years old ice-fields, 3 to 12 km the size, though more frequently of 3—4 km,

form a still larger expence of ice, divided by wide bands of ice-pack and open water. In the region of these bands the strongest pressure occurs, resulting often in high ridges of hummocks. Hummocks composed of smashed ice were met only in these regions.

During the winter period an increase of the area of the ice-cover takes place. This increase is due, first, to the formaton of belts of fresh ice along the edge of old fields, and secondly, to the locking of large open water spaces. Both the former and the latter processes were observed throughout the drift. Thus, for instance, in February, when we started out in search of Cherevichny, at a distance of 2 km from the station we discovered a band of newly frozen water, stretching over a distance of 5 km and having half a kilometer and even a full kilometer in width. Judging by the absence of snow heaps on their surface, these water spaces must have been locked with ice in January. Identical small plains of smooth fresh ice were occurring occasionally in other places in the vicinity of the station.

VIBRATIONS OF THE ICE-COVER

The vibrations of the ice-cover were particularly manifest during the six-day gale, which swept uninterruptedly the last six days of January. The vibrations were detected through the oscillations of the bubble within the levels of the astronomical theodolite fixed on the surface of the field. The period of vibrations was 10—12 seconds. These vibrations preceded the breaking of the ice-floe on February 1. On the 25th of January, at the beginning of the storm, at half a kilometer's distance from the station, two parallel cracks were discovered, running perpendicular to the direction of the dominating northern and north-western winds. Soon a third crack appeared, running approximately in the same direction. Along those cracks, running along the crests of the ice-waves, commenced the disintegration of our ice-field. Apparently, the strong wind produced an undulating vibratory motion of the ice-cover, similar to the vibration of an elastic plate freely floating on the surface of a fluid.

North Pole station

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GEOPHYSICS

GEOPHYSICAL AND ASTRONOMICAL OBSERVATIONS

By E. K. FEDOROV

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The results of our observations will be worked through in a few months. At present we only want to acquaint our readers with the fundamental data obtained in result of a preliminary treatment and give an account of the ways and means by which all the investigations were carried out.

1. Meteorological Observations. Weather observations were effected four times a day at 0, 6, 12 and 18 o'clock of the third zone time. Every time readings of the following were taken: temperature of air, pressure, humidity, velocity and direction of wind; while visibility in the horizontal direction was also noted as well as cloudiness and shape of clouds. For the necessary equipment we had a small instruments cage with which many of our readers are probably acquainted from photographs. It contained five thermometers, a thermograph and a Kuznetzov hygrometer. Two aneroids, a barograph and spare meteorological equipment were housed in a special box in our tent. The thermographs and barographs gave diurnal records. Wind velocity was measured with a hand anemometer. During the whole time we used only one set of meteorological equipment. Before starting on the expedition all the apparatus were duly tested in the Main Geophysical Observatory where they are now being checked again.

Table 1

Temperature by Time-Periods.

Month	Latitude	Longitude	Mean $t°$	Max. $t°$	Min. $t°$
May (21—31)	89°20′	300°	−10.0	− 2.0	−16.5
June	88°50′	350°	− 2.5	+ 1.0	− 8.0
July	88°20′	355°	− 0.0	+ 2.0	− 2.0
August	87°30′	000°	− 1.2	+ 0.5	− 8.0
September	86°20′	000°	−12.1	− 3.0	−24.0
October	84°40′	005°	−20.8	−16.5	−35.5
November	83°30′	355°	−24.7	−12.5	−35.5
December	81°30′	353°	−21.7	− 6.0	−35.5
January	77°00′	350°	−26.5	−10.0	−44.5
February (1—19)	73°00′	343°	−13.3	− 0.5	−24.3

The results of our meteorological observations were broadcast over to the mainland and could thus be made use of by all those who were in need of them. Below are to be found the mean temperatures observed during each month.

In June and July strong thawing was observable: in fact, all the snow-cover melted away, whose thickness had on average been about 40 cm. The surface layer of ice began to melt too, disintegrating into separate grains. In August thawing was over, the surface of numerous pools and small lakes formed on the ice-floe became covered with ice and the accumulation of a fresh snow-cover began anew. General weather conditions differed greatly during the first part of our drift in the Polar basin and at the end when we were traversing the Greenland Sea. In the north we had no strong winds, nor were there any sharp pressure differences. At the same time, in the Greenland Sea severe storms were of frequent occurrence, while pressures of terminal intensity were also observed. During almost the whole of the time, with the exception of July, the predominant directions of the wind were north, north-north-west and north-west.

2. Magnetic Determinations. Our magnetic measurements were carried out with the aim of providing material for a magnetic chart of the Arctic; in other words, we had in view to investigate the geographical distribution of the elements of terrestrial magnetism. For our measurements we used a Shasselon magnetic theodolite into the design of which rather considerable modifications were, however, introduced. Thus, for instance, the theodolite was supplied with a special device for determination of the inclination angle after the method of Lamon. Declination was determined in the usual way. The horizontal component was determined by the method of deflection; the constancy of the magnetic moment of the deflecting magnets was determined by means of the mutual checking of the four magnets which we had, two of which were made of alloys with a particularly stable magnetic moment. It is well known that in the Arctic the magnetic field is liable to be very unsteady. Variations, partly regular or periodic and partly irregular, call forth a considerable deviation of the magnitudes of magnetic elements from their mean «normal» values. In order to take due account of the distorting effect of such variations we brought along with us magnetic variometers with visual readings. With the help of these instruments it was possible to watch variations in the magnetic field and, carrying out parallel measurements of magnetic elements, to exclude the effect of variations from the respective values. Variometers were as a rule set up for one day. Readings were taken every two minutes during 30 minutes out of every hour of a day. At the beginning and at the end and sometimes also in the middle of this diurnal series of variation-readings, measurements of magnetic elements were effected with the help of a theodolite. In this way we were able to obtain magnitudes closely approaching the mean diurnal values of magnetic elements.

It stands to reason that we could use the variometers only when the rotation of our ice-floe was inconsiderable, since these apparatus require either

a permanent or at any rate a but slightly changing orientation. We did so until the beginning of November. Then we began to notice that our ice-floe began rapidly changing its orientation. This was presumably connected with our approach to the coast of Greenland. Be this as it may, the rapid rotation of the floe (6—10° a day) prevented our further use of magnetic variometers. In the subsequent, we were obliged to make theodolite measurements as often as possible, in order, by means of grouping together several series of measurements, to obtain the most exact mean values of the elements. The counts of magnetic variations as effected by us not only permit to define with great accuracy the values of the elements, but afford also the possibility of elucidating certain peculiarities of the course of both recurrent and non-periodical variations of the magnetic field in the Central Arctic. We recorded variations of declination from 1 to 2 degrees on calm days and up to 10 degrees on magnetically perturbed days. The amplitude of the horizontal component was from 100 gammas on calm days to 500 gammas on perturbed days.

Within the period of the drift 55 series of measurements of declination and the horizontal component were accomplished, as well as 36 series of inclination measurements. These measurements can be conveniently grouped for 27 points fairly evenly distributed along the path of the drift.

Table 2

Table of Values of Magnetic Elements

№	φ	λ	D_{Gr}	H	I
1	89°25′	305°	39.8	0.0314	86°36′
2	88°54′	343°	36.5	0.0335	86°23′
3	88°51′	359°	41.3	0.0357	86°19′
4	88°30′	348°	37.6	0.0355	86°10′
5	88°15′	356°	35.1	0.0393	85°54′
6	87°59′	357°	32.3	0.0389	85°56′
7	87°10′	002°	30.8	0.0430	85°44′
8	86°39′	359°	27.3	0.0452	85°19′
9	85°58′	001°	27.6	0.0474	84°57′
10	85°40′	001°	26.0	0.0499	84°47′
11	85°08′	006°	23.7	0.0516	84°29′
12	84°37′	003°42′	26.1	0.0534	84°20′
13	84°07′	003°00′	24.0	0.0567	83°57′
14	83°47′	357°30′	25.7	0.0641	83°12′
15	82°57′	354°20′	22.9	0.0613	83°18′
16	82°27′	353°10′	19.2	0.0612	83°10′
17	81°51′	352°50′	20.8	0.0643	82°55′
18	81°02′	353°10′	20.2	0.0667	82°26′
19	80°00′	353°05′	20.2	0.0727	81°58′
20	79°36′	352°43′	19.3	0.0732	81°55′
21	78°58′	350°57′	17.6	0.0744	81°45′
22	78°16′	349°40′	16.6	0.0774	81°28′
23	77°46′	347°55′	14.9	0.0783	81°17′
24	77°17′	347°35′	13.1	0.0809	80°46′
25	76°38′	346°25′	10.4	0.0797	81°12′
26	76°29′	346°25′	13.2	0.0800	—
27	71°50′	339°45′	—	0.0968	—

For characterizing the direction of the horizontal component of the magnetic field we do not give here the commonly used magnitude of mag-

netic declination, i. e. that of the angle between the geographical and the magnetical meridian; and this for the reason that near the pole at points not far distant from one another and with one and the same direction of the magnetic meridian in both, this angle was found to vary greatly.

The distribution of the earth's magnetic field near the geographical pole may be by far better visualized by means of taking the angle between magnetic meridians and a certain direction which has been chosen once and for ever. We give here, instead of declination, the angle between the magnetic meridian at the given point and the direction of the Greenwich meridian. Variations of this angle testify to the actual non-parallelism of magnetic meridians at the points under comparison. To pass over from this «quasi-declination» to the usual declination, resort is had to the following formula:

$$D_{Gr} = D - \lambda.$$

Generally speaking, for purposes of navigation the use of the ordinary meridians in regions lying close to the pole is less convenient than to having recourse to a system of parallel lines, running parallel to a certain single meridian.

As seen from the table, the geographical determination of the magnetic field in the region investigated is remarkable for its uniformity. If we compare our results with maps of the magnetic field in the Arctic as made by different authors, for example by Fisk and Weinberg, we shall at once see very good agreement between the actual and the theoretically assumed distribution of the horizontal component and the angle of inclination. As regards the direction of the magnetic meridians, it differs near the pole from the magnitude theoretically assumed by some 12—15 degrees. This difference is reduced to a small value at about 80° N. lat., while further the actually observed declination is in quite good agreement with maps. This brings strong evidence to bear in favour of the absence of appreciable anomalies of the magnetic field in the Central Arctic.

3. The Aurora Borealis. From the onset of darkness in early October and up to the end of our drift we conducted regular visual observations of the aurora borealis. Every hour the meteorologist on duty entered in the logbook the location, the form and the intensity of the light, noting also conditions of visibility and cloudiness. In December and January we had frequent northern lights often reaching considerable intensity.

4. Observations of Atmospheric Electricity. The last field of observations in the electro-magnetic complex consisted in measurements of the gradient of the atmospheric electricity potential. These were carried out by means of a bifilar electrometer and collectors covered with radioactive substances. All in all we conducted 5 series of diurnal measurements, the work being conducted on days which were the calmest from an electro-meteorological point of view, i. e. free from wind and clouds. It was found that the mean value of the gradient was as high as 120 volts per meter, and we were able to trace a diurnal course of oceanic type with an

amplitude of almost 90 volts per meter. All these observations were conducted in the second half of the summer at 88° and 86° N. lat.

5. Gravitation Measurements. To measure the force of gravity on a drifting ice-floe with a pendulum appeared to me the most difficult problem among all the tasks we had before us. As is well known, these observations require great stability of the apparatus and constancy of all observation conditions. However, it was found that the motion of ice usually took place so uniformly that it hardly interfered with our observations. I say «hardly», because sometimes we noticed thrusts running over the ice; hardly perceptible to the senses, they were nevertheless apt to distort the swinging of the pendulum. Within the last period of the drift vibration of the ice was also observable, which likewise impeded the observations. All these hindrances presented, however, no serious obstacles to the carrying out of our task.

Our pendulum set was manufactured at the Leningrad Astronomical Institute. In this set simultaneous observations were made of the oscillations of four minimum pendulums. Measurements of the periods were accomplished with the help of an electro-magnetic counter. A chronometer closing the counter circuit was kept in a thermally lagged box placed in our tent. From it wires were extended to the observation spot. In summer the observations were made in the tent and from September on—in an ice-house. The apparatus proved fit, the design of the counter and all its parts having permitted us to work with it at low temperature without any particular difficulties.

Observations were ordinarily carried on for three days running with 7 measurements of the period of each pendulum within an 8 hours interval

Table 3

Preliminary Results of Gravimetrical Observations at the North Pole Station

Item N°	φ	λ	g	$g - g_{1930}$
2	88°58′	331°	983.232	+ 8
3	88°49′	335°	983.217	− 6
4	88°03′	355°	983.205	− 15
5	87°10′	002°	983.218	+ 5
6	86°44′	359°	983.222	+ 13
7	86°02′	001°	983.226	+ 25
8	85°32′	002°	983.207	+ 13
9	84°58′	006°	983.199	+ 13
10	84°21′	003°	983.206	+ 31
11	83°58′	001°	983.213	+ 45
12	83°36′	357°	983.182	+ 21
13	82°52′	355°	983.134	− 12
14	82°08′	352°2	983.161	+ 33
15	81°20′	353°2	983.146	+ 39
16	80°20′	352°8	983.142	+ 63
17	79°30′	353°0	983.156	+103
18	78°30′	350°0	983.038	+ 19
19	77°55′	348°2	983.011	+ 13
20	77°00′	347°5	983.067	+ 94
21	76°15′	346°3	983.007	+ 75

every day. In the summer season, when the ice was melting, it was every time necessary to erect the apparatus and counter anew before each interval. Beginning from September and up to the end of the drift it was possible to use all the time one and the same set-up of the apparatus and counter.

Before the start of the expedition this apparatus was tested at the Astronomical Institute. The initial value of the period of every pendulum was determined at Pulkovo. Now again tests have been made at Pulkovo. It has been found that each pendulum has somewhat extended its period (respectively by 14, 32, 6 and 28 units of the seventh sign) which does not exceed the range of variations commonly taking place in gravimetric expeditions. At present, preliminary computations of the measured magnitudes of gravity have been accomplished. Comparison with the magnitudes afforded by the international formula, given by Kassini in 1930, shows the actual distribution of gravity to exhibit a positive anomaly along practically the whole of the path of our drift reaching its highest value of 100 milligals upon passing the sharp elevation of the sea bottom off the coast of Greenland.

Since in the calculations performed no allowance was made for certain corrections, for instance the correction for the swinging of the pendulum-support together with the pendulum, corrections for the transmitting hours of wireless stations and a few other ones, it will be but quite natural, if the results of the ultimate calculations will differ somewhat from the data given in the table.

6. Astronomical Determinations. The coordinates of our ice-floe, steadily pushing its way over the ocean, were obtained from astronomical determinations. As is well known, for the determination of one line of a position it is necessary to measure the height of some heavenly body. In course of the drift 534 series of measurements of various luminaries were carried out; in the day-time—those of the sun and sometimes the moon; in the night—those of the stars; 370 series of measurements of the azimuths of luminaries were also made. From these measurements it was possible to calculate the coordinates of 143 points on the map. On the average, we succeeded in carrying out our astronomical observations every other day, the longest period of time during which clouds prevented us to see the sky extending over no more than 5 to 6 days. All the measurements were effected by means of a Wilde theodolite of the 1937 design. The instrument proved convenient in work. The accuracy of the measurements of the coordinates may be set at 0.2 of the arc. We say «may be», because on the spot we did not calculate the coordinates with such full precision as would have been possible from the observations. This would have taken up too much time. The necessary steps were taken to simplify inasmuch as possible astronomical calculations. Thus, special astrographs were calculated for us under the supervision of Prof. Jongolovitch which afforded the possibility of quick and ready determination of latitude and local sidereal time from the height of two stars. Prof. Kavraisky also worked out for us most convenient formulae and nomograms enabling us to perform easy computations of the height and azimuths of celestial bodies within the polar region. These

formulae are based on the fact that near the pole both the height and the azimuth of luminaries can be represented in the form of series having as their first term respectively declination or hour-angle, while it is quite possible to make convenient nomograms for the further small terms—the functions of latitude and local time.

To the south of 80° we conducted all calculations of astronomical observations in the usual way.

Thus, astronomical observations showed us that the ice-floe was moving steadily onward, keeping, upon the whole, to the direction of the Greenwich meridian. The speed of our progress failed, however, to be the same during all the time. According as we drifted down towards the south, the mean daily velocity of the drift increased from 2.6 miles, which we used to cover at the beginning of drift, to 12 miles at 70°. Originally it seemed that the drift of the ice-floe depended wholly upon wind. However, while still in our camp, we made certain calculations which showed that the wind blowing in our region could by no means be alone held responsible for the drift. Indeed, if we are to look at the graph of the wind and if we are to compare it with the curve of our drift, we shall not be slow to see that there exists here no similarity between the two lines, which similarity could certainly have been traceable had the ice-floe been merely acted upon by the local wind. For instance, the resultant of wind action for the month of July is fairly small, while in that very same month our ice-floe advanced southward quite considerably. Comparing the effect of wind in different directions, it was found possible to ascertain that, apart from the motion produced by wind, the drift was characterized by a certain component independent of local wind and mainly directed southward. This component also increased in the southern part of our way. Between 90 and 85° its magnitude was about a mile a day while it reached 6 to 7 miles a day near 71°. The action of the local wind may be said to have been superimposed upon this constant drift. The wind drove the ice-floe at a rate which constituted about $^1/_{100}$ of the wind velocity in a direction deviating to the right-hand from the direction of the wind according to the well-known rule of Coriolis. It seems to us that constant drift of ice, and at any rate that observable in the Central Arctic, is due to the general distribution of wind in the Polar basin, which produces in the ocean a certain general ice-drift, distorted in different places by the effect of the local wind.

North Pole station.

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GEOPHYSICS

THE DRIFT OF ICE-FIELDS

By W. W. SHOULEJKIN, Corresponding Member of the Academy

In the present work the elements of the drift of ice-fields are determined according to the given elements of wind. The coefficients found in the equations may be easily determined on the ground of the rich material gathered by the Soviet Polar Drift Station. Then, proceeding from the theory suggested it will prove possible to foretell the progression of the ice-fields on the basis of the synoptical weather charts.

Using the communications received from the Drift Station, one can make a series of quantitative conclusions. In particular, one can draw a conclusion on the origin of the currents, existing in the region crossed by Papanin's ice-field at different stages of the drift.

Let us introduce the following denotations:

T_v — the force of friction between air and ice (dyne/cm²);
T_i — the force of friction between ice and water (dyne/cm²);
k_a and k_w — the respective coefficients of surface friction;
μ — the coefficient of the internal turbulent friction in water;
δ_a und δ_w — the densities of air and water respectively;
D — the depth of friction (cm);
ω — the angular velocity of the Earth's rotation round its axis;
$\overline{\omega}$ — the same multiplied by the sine of latitude;
A — the wind factor (the empiric coefficient for the sea not covered with ice);
m — the mass of ice for 1 cm² of the surface of the field (g/cm²);
V — the velocity of the wind (cm/sec).

Then first of all we shall be able to establish a connection between D and w.

Namely, on the basis of the well-known Eckmann's equations

$$D = \pi \sqrt{\frac{\mu}{\delta_w \omega}}; \quad w = \frac{T \cdot D}{\mu \pi \cdot \sqrt{2}}$$

and of equally known empiric relations

$$T = k_a \cdot \delta_a \cdot V^2; \quad w = \frac{A \cdot V}{\sqrt{\sin \varphi}}$$

it proves that

$$\left.\begin{aligned} D &= N \cdot w, \\ N &= \frac{\pi}{\sqrt{2}} \cdot \frac{k_a}{\omega A^2} \cdot \frac{\delta_a}{\delta_w}. \end{aligned}\right\} \qquad (1)$$

where

The coefficients k_a and A have been determined with great reliability by a number of authors:

$$k_a = 2 \cdot 10^{-3}; \quad A = 1.27 \cdot 10^{-3}.$$

Therefore the numerical value $N = 473$ found according to the equation (1) may be taken as sufficiently reliable.

If w is the velocity of the surface current not on the free water but under ice, then the picture of turbuleht processes may be somewhat changed and therefore change μ and D. However, it is quite doubtless, that this detail has no practical value: it causes variations of the coefficient N which do no exceed the limits of usual errors.

Let us take a certain drift velocity $\vec{u}$ and direct along it the axis of coordinates X. The axis Y will be get by the revolution of the first axis to a right angle counter clockwise in the horizontal plane. The axis Z will be directed vertically downwards.

The force of friction between the moving ice and the surface water causes a drift current under the ice with the surface velocity $\vec{w}$.

The angle $\alpha = \angle \vec{w}, \vec{u}$ is unknown as yet. The force of surface friction itself, acting on the water, must coincide in its direction with the velocity of the movement of ice in respect to the water, i. e. with the vector $\vec{r}$ shown in Fig. 1.

It is easy to see that

$$\vec{r} = \vec{u} - \vec{w}. \tag{2}$$

The force of friction $\vec{T}_i$ acting on the ice from the water has the direction opposite to $\vec{r}$ and is equal in its absolute value to

$$T_i = k_w \delta_w r^2. \tag{3}$$

On the basis of (3) and of the two above Eckmann's equations it is easy to draw

$$w_i = \zeta \cdot r,$$

where

$$\zeta = \sqrt{\frac{\pi k_w}{N\bar{\omega} \cdot \sqrt{2}}}. \tag{4}$$

As the drift current is caused by the force $-\vec{T}_i$, then:

$$\left.\begin{aligned} &\angle \vec{w}_i, (-\vec{T}_i) = \angle \vec{w}_i, \vec{r} = \tfrac{\pi}{4}; \\ &\angle \vec{r}, \vec{u} = \tfrac{\pi}{4} - \alpha. \end{aligned}\right\} \tag{5}$$

By means of simple trigonometrical transformations we can show on the basis of (4) and (5) that

$$\operatorname{ctg} \alpha = \zeta \sqrt{2} + 1. \tag{6}$$

Equally simple reasoning shows that

$$w_i = u : \left[\cos \alpha + \frac{1}{\zeta} \cos \left(\frac{\pi}{4} - \alpha \right) \right]; \tag{7}$$

$$r = u : \left[\zeta \cos \alpha + \cos \left(\frac{\pi}{4} - \alpha \right) \right]. \tag{8}$$

The relations (3) and (5) allow us to find the projections of the force $\vec{T}_i$ on the axes X and Y. As to the projections of Coriolis force, acting on a unity column of ice with the section area 1 cm², they will be

$$C_x = 0; \quad C_y = -2m\bar{\omega} \cdot u. \tag{9}$$

The wind causing the motion of the ices with the velocity u, must develop on the upper surface of the ice the force T_v which is equal to the resultant f of the forces $\vec{T}_i$ and $\vec{C}$ along the modulus and having the opposite direction. Then it will prove that for the angle $\psi = \angle \vec{V}, \vec{u}$ can be deduced the following relation:

$$\operatorname{tg}\psi = \operatorname{tg}\left(\frac{\pi}{4} - \alpha\right) + \frac{B}{u},$$

where

$$B = \frac{2m\omega\left[\zeta\cos\alpha + \cos\left(\frac{\pi}{4} - \alpha\right)\right]^2}{k_w \cdot \delta_w \cdot \cos\left(\frac{\pi}{4} - \alpha\right)}. \qquad (10)$$

Thus, the angle ψ depends on the drift velocity, and consequently, on the velocity of the wind which causes the drift. It lies within the limits

$$\frac{\pi}{2} > \psi > \left(\frac{\pi}{4} - \alpha\right) \qquad (11)$$

tending to the top limit $\left(\frac{\pi}{2}\right)$ under the decrease of the velocity and to the lower one, under the increase of the velocity. On the ground of (6) and (10) the angle ψ must depend on ζ and therefore on k_w.

The absolute value of the resultant f is determined by the projections obtained:

$$|T| = |f| = \frac{k_w \cdot \delta_w \cdot u^2 \cdot \sin\left(\frac{\pi}{4} - \alpha\right)}{\left[\zeta\cos\alpha + \cos\left(\frac{\pi}{4} - \alpha\right)\right]^2 \cos\psi}. \qquad (12)$$

On the other hand, the same force is expressed by the square of the wind velocity, as was shown above. Treating both expressions as identical, we shall obtain a particularly important relation (after simple transformations):

$$\frac{u}{V} = \left[\zeta\cos\alpha + \cos\left(\frac{\pi}{4} - \alpha\right)\right]\sqrt{\frac{k_a}{k_w} \cdot \frac{\delta_a}{\delta_w} \cdot \frac{\cos\psi}{\sin\left(\frac{\pi}{4} - \alpha\right)}}. \qquad (13)$$

The relation of the drift velocity to the wind one depends on the latter. Under slight winds, $\frac{u}{V}$ tends to nought. With the growth of the wind velocity, $\frac{u}{V}$ at first grows rapidly, then slower, as $\cos\psi$ approaches the limit value equal to $\cos\left(\frac{\pi}{4} - \alpha\right)$.

If we take one of the possible numeral values of the coefficient k_w, e. g. $k_w = 0.004$ and $m = 270$, then on the basis of the theory expounded, the vector diagram will take the form represented in Fig. 1, and the connection of the quantity $\frac{u}{V}$ with the wind velocity V is expressed by the curve $\frac{u}{V}$ in Fig. 2.

Further, proceeding from this curve, we draw the curve u which expresses the dependence of the velocity of drift immediately upon wind velocity.

In the same Fig. 2 the curve ψ calculated from the equation (10) represents the law of the variations of the angle between the vectors $\vec{u}$ and $\vec{V}$.

Before comparing the theoretical conclusions to the results of the immediate observations of the Soviet Polar Drift Station, let us consider the period after the beginning of the wind work, after which we may practically take the movement of ices as stationary. This problem may be solved analytically for two most simple cases:

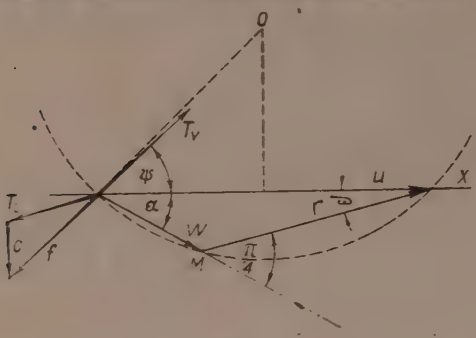

Fig. 1.

a) *The velocity of drift is contemptibly small, and therefore the force of friction between water and ice may be neglected in comparison with the Coriolis force.*

In this case it proves that the ice-fields will perform two motions superposed one on the other: they will have a progressive motion with the velocity u_2, where

$$u_2 = \frac{T_V}{2m\omega}; \quad \vec{u}_2 \perp \vec{V}, \qquad (14)$$

and simultaneously every point of the ice-cover will delineate a circle with the radius R in the horizontal direction; besides,

$$R = \frac{T_V}{4m\omega^2}. \qquad (15)$$

The angular velocity here will be equal to double angular velocity of the Earth's rotation around its axis multiplied by the sine of latitude. The compound motion of every point of the ice-fields will be obviously directed along a cycloid in the horizontal plane.

b) *The velocity of the drift is so large that the Coriolis force may be neglected in comparison to the force of friction between ice and water.*

In this case, in the period t after the beginning of the wind work the velocity u of the drift of the ice-fields will prove to be

$$u = \frac{1 - e^{-\beta t}}{1 + e^{-\beta t}} \cdot \xi. \qquad (16)$$

It is easy to understand that ξ expresses the value of the velocity of the stationary movement, to which u tends with $t \to \infty$. The coefficient β is connected with this value, as it can be shown. Namely:

$$\beta = \frac{2T_V}{m \cdot \xi}. \qquad (17)$$

Having taken that $T_V = 3$ dyne/cm², $m = 270$ g/cm², we shall find that on the basis of (16), (17), the movement becomes stationary very rapidly: already in an hour after the beginning of the wind work the drift velocity attains the value equal to 85% of the stationary one. In one hour and a half it attains already 96%, and in two hours — about 99%.

In reality the non-stationary movement proceeds according to an exceedingly complicated law which cannot be exactly analyzed. However, we can show, by means of simple reasoning, that the order of the term, during which the movement may be practically considered as settled, does not differ in any from that corresponding to the second of the above-examined cases. Namely:

We can practically consider that in an hour or in an hour and a half after the beginning of the work of the wind, the progressive moment of the ice-field is stationary settled. As to the rotationary

movement, noted in the first simplified case, it does not damp so rapidly. This circumstance, however, has no practical value: all the points of the ice-fields describe circles of the same radius, which decreases in time; the period of a complete revolution of the corresponding component of velocity is equal to 12 hours. Consequently, this component does not practically influence the mean daily velocity of the drift.

From the coordinates daily communicated by the Soviet Polar Drift Station, one can calculate the mean velocity of the drift for each day (with some exceptions) and then find its components: along the meridian and normally to the latter. For the first of them the southward direction will be taken as positive; for the second, the westward one. The velocity of wind was given in points, thus its recalculation in terms of cm/sec will give rise to some errors. The directions of the wind were given to within one eighth of the right angle.

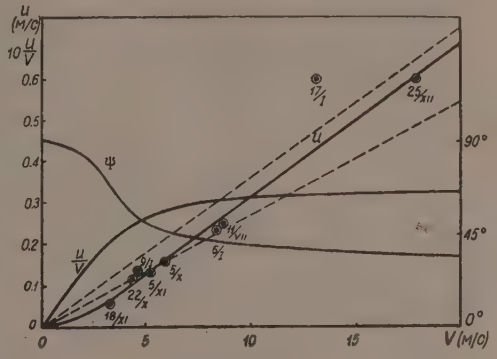

Fig. 2.

Consequently, for a preliminary comparison of the theory with the results of observation, in the present work, it would be expedient to assume that the drift velocity deviates to the right from the wind velocity, on the average to an angle about 45° (considering the diagram of Fig. 2).

In this case, however, the active component, causing the drift to south will be the projection of the wind velocity on the direction NW→SE. The active component, causing the drift to the west, will prove to be the projection of the wind velocity on the direction NE→SW. To check the theory it is necessary to compare the curve of the change (in time) of the meridional component of the drift velocity with the curve of the change of the corresponding active component of the wind velocity. The same comparison is to be made for the drift component normal to the meridian. The most precise results are obtained for the meridional component of the drift: at many parts of the way one of the curves compared copies the course of the other very well.

The meridional components of the drift velocity, which correspond to these parts of the way, free from external obstacles, are represented in the diagram of Fig. 2 by points, the abscissae of which correspond to the active components of the wind velocity.

A rather more complicated picture is obtained for the components of the drift velocities normal to the meridian, especially at the stages when the ices were moving along the Greenland coast. Naturally enough, the coast exerted its influence on these components. The whole of the material contained in the preliminary communications, not only its chosen most precise parts, may be used for the comparison with the theory.

Indeed, let S (+) and S (—) denote the areas of the curve of the changes (in time) of the meridional component of the drift velocity, lying above and under the axis of abscissae and calculated for some definite period (e. g. 50 days). Let F (+) and F (—) denote similar areas for the curve representing the variation of the corresponding active component of the wind velocity (i. e. active in respect of meridional drift).

Should the ratio u/V remain constant for all the velocities of wind (and not only for the prevailing velocities exceeding 7 m/sec), then the comparison of the two ratios $\frac{S(-)}{F(-)}$ and $\frac{S(+)}{F(+)}$ would enable us to judge with accuracy of the character of currents in the region under the investigations of the Drift Station. Namely, the equality of these ratios would attest the absence of currents of non-drift origin in this region. As a matter of fact, the non-lineal dependence of u on V, expressed by the diagram of Fig. 2, makes us expect some though not considerable deviations from equality.

In order to estimate the range of error and thus to establish or to reject the existence of non-drift currents in the region explored, it is necessary to find the value of the «correcting» area σ which would satisfy the condition

$$\frac{S(-)+\sigma}{F(-)} = \frac{S(+)-\sigma}{F(+)}.$$

Calculations show that at all the 50-day intervals of the drift the «correcting» area σ corresponds to certain «correcting» increments of the velocities not exceeding 1—2 cm/sec. Consequently, these corrections may be put down exclusively to the deviations of $\frac{u}{V}$ from constancy.

The analysis discovers no traces of currents of non-drift origin throughout the drift of the Soviet Polar Station.

In particular the origin of the so-called East-Greenland current is cleared up: it is also of purely drift origin, caused by the movement of ice. The considerable constancy of this current is accounted for by a similar constancy of winds working off the Greenland coast.

These winds are undoubtelly of monsoon type: they are due to considerable difference of temperatures between the air over the sea and the eternal ices of Greenland glaciers.

A detailed investigation bearing on the problem and the deduction of all the above relations will be published in the Transactions of the Department of Mathematics and Natural science of the Academy of Sciences (Geophysical and Geographical series). The exact determination of the coefficients and the construction of more accurate diagrams will certainly be carried out best of all by the authors of the excellent observations of the Soviet Polar Drift Station themselves.

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GEOPHYSICS

FROZEN GROUNDS RECEDE

By S. P. KACHURIN

(Communicated by V. A. Obruchev, Member of the Academy, 25. III. 1938)

94 years have elapsed since Middendorff made his famous «Journey to north-eastern Siberia». For the first time quite trustworthy data were then obtained by him on the character of frozen grounds and their wide distribution in Siberia, though their existence seemed dubitable to many, even the foremost people of that time.

One of the first places, where Middendorff carried out geothermic measurements at a relatively great depth (down to 41 feet) was a site in the vicinity of Staro-Turukhansk (Old-Turukhansk). He held that Turukhansk was situated at the southern border of the zone of frozen grounds. Since then there have been no data available on frozen grounds along the middle course of the Yenissei river. Therefore in all the available charts on the distribution of frozen grounds on the territory of USSR their southern boundary has a northward band near Turukhansk, and thence turns sharply southward, running almost on a straight meridional line, along the right shore of the Yenissei river and descending considerably farther south from the town of Krasnoyarsk. All efforts to explain this projecting of the frozen grounds border were based, for lack of actual evidence, on mere speculations.

Complete obscurity in regard to frozen grounds and the necessity for more accurate definition of their southern boundary within the Yenissei river basin prompted the Frozen Grounds Committee of the Academy of Sciences of USSR to organize in 1937 an expedition on the investigation of frozen grounds in the middle parts of the Yenissei river course, and particularly its left shore. Besides, it was of great interest to take repeated observations at the very locality where observations had been carried out by Middendorff and to see under the thermal aspect what has become of the frozen grounds in the region of Turukhansk, after nearly a century has passed from the time of Middendorff's investigations (1843). The fact that the date of the first observations was rather remote from our times impelled the necessity for taking new observations in the same places. It was of special interest indeed to repeat observations at the identical point after a great lapse of time, in connection with the question of degradation of frozen grounds which was theoretically proved by M. I. Soumgin for the southern margin of frozen grounds upon records taken at the Frozen Grounds Station at Skovorodino. An affirmative (or negative) answer to the question of degradation of frozen grounds is known to be of great importance both for

the theory and practice. Upon the process we find there depends whether we have to leave or destruct the frost when constructing municipal, industrial and, particularly, agricultural buildings in the frozen ground zone.

In this brief article we shall not go into details in describing all the results of the works carried out by the Yenissei Frozen Grounds Expedition, we shall merely state that according to new data the border line of frozen grounds should be drawn 250 to 300 km south of Turukhansk. North of this line only small isolated areas of unfrozen ground are encountered near Yenissei. In the region of the lakes Dashkino and Nalimye (named in the maps lake Kapydack and lake Pakulskoye respectively), at the Yenissei-Tazov watersched, were met forms of a relief, which represent relics of the Glacial Epoch. In the month of August they were all bound by the frost at a small depth (0.5 to 1.5 m). Total thickness of the frozen grounds could not be determined by means of the instrument available. Observations made at a depth of 10—11 m schow an increase of negative temperatures with depth, and consequently a considerable thickness of frozen grounds in the region of the aforementioned watershed. As it extends in the direction from the watershed towards the Yenissei river, the upper surface of the frozen grounds on the whole gradually sinks, and we struck it only at separate points close to the relief surface (trading settlement Surgutikha); however, in immediate vicinity of the Yenissei river there were often no frozen grounds detected by us, and this is the reason to consider such areas as thawed or pseudo-thawed earth islets amidst continuous frozen grounds.

We are going to give a more detailed account of the results of boring and of thermic observations taken in the region of Old-Turukhansk, on the basis of which some suggestions are made constituting the subject matter of the present article.

The position of bore-holes was entered by Middendorff in a schematic representation, from which it was not possible, after the lapse of almost a century, to determine the precise location of the bore-holes. Moreover, during that period of time the face of the locality has changed (the old forest was cut down, a new one has grown, and so on), and no special marks had been left by him. However, taking advantage of his description and the available schematic chart, new holes were drilled by us at points which may be believed to be quite close to Middendorff's bore-holes. By way of analogy with Middendorff's data, three holes were drilled by us, and all of them reached greater depths than the corresponding holes bored by Middendorff.

In the process of boring we found out that on the site of the three bore-holes the geological structure and the lithological composition of rocks are more or less identical with both slight variations for each site.

In all of the three bore-holes right underneath the upper vegetative layer there are deposits of clayey soil, changing into clayey sand 3.5 to 4.0 m thick, further appears sandy soil interbedded with clay and fine-grained sand down to a depth of 6—10 m; further down there is silt-clay with intermittent solid beds of sandy soil to a depth of 12—13 m; still lower lie deposits of medium- and coarse-grained sand traced by us to a depth of 16 m. The characteristics of these layers testify to their alluvial origin.

The distribution of moisture in the soils was according to our observations substantially determined by the stratigraphy of loose deposits, being dependent moreover on the relief of the locality, which owing to the more elevated position of the site, compared to the surrounding sloping territories, and the presence of gully-holes contributed to a regular drainage of the atmospheric precipitations. In the upper part of the slit there is a rather thick bed of clayey soil which being waterproof prevented a penetration of

vadose waters into the heart of sands and sandy soil. Therefore the general moisture of the soil (see graph, Fig. 1) was rather low. On the contrary, in most cases the sand and clayey soil layers were often so dry that it was with great difficulty that we succeeded in extracting them from the bore-holes by means of our instrument, because upon the slightest vibration of the instrument they were easily shaken off, and moreover, the sides of the bore-holes often caved in which made the drilling rather difficult and attested great dryness of the rocks.

In two bore-holes (1st and 2nd), at depths of about 7 and 16 m, ground water appeared, whereas the third bore-hole remained absolutely dry throughout the entire depth (11 m) and attained even greater dryness with depth.

The results of temperature measurements in the grounds, upon our observations, showed in all three bore-holes higher temperatures as against the corresponding depths and bore-holes according to Middendorff. Temperature plots shown in Fig. 1 give a graphical representation of temperatures of

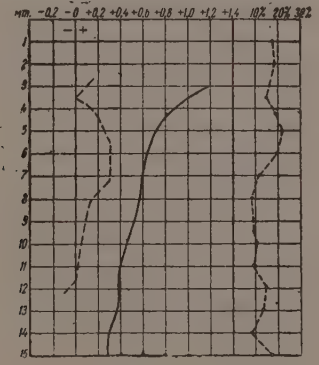

Fig. 1. Geothermic curves and curves of soil moisture.

— — — temperature 1843, Middendorff, Member of the Academy.
——— temperature 1937, S. Kachurin.
..... natural moisture.

grounds, in conformity to the measurements of Middendorff in 1843, and our own in 1937. The temperature measurements made by Middendorff with the Reaumur thermometer are given in terms of Celsius degrees. As it may be seen from the tables, the temperature curve obtained in 1937 shows its deep portion to deviate by 0.3—0.4° towards positive temperatures, which is an evidence for a general warmer condition of the ground as compared with that in 1843. Besides, in the 2nd hole bored by Middendorff, to a depth of 12.5 m (41 ft.) frozen ground was revealed by him with a temperature of minus 0.1°, while all of our three bore-holes passed through strata with positive temperatures, and even at a depth of 15 m (in the 2nd bore-hole) thermometers recorded a temperature of +0.3°C. This circumstance bears evidence of the sinking of the upper border of frozen grounds, since there are no reasons to doubt the perfect accuracy of the temperature measurements made then as well as now. From the fact established by us that at the depth of 15 m the temperature of the ground was +0.3°C, and the corresponding geothermic gradient, we may for the given area compute the actual boundary of the upper surface of the frozen grounds, if it is still there, as being at a depth of no less than 20—23 m, i. e. from 10 to 12 m lower down than the one determined by Middendorff in 1843.

The difference of almost 6 months, which with respect to the time of year separated Middendorff's observations (March-April) from ours (September), so that we may approximately refer the former to the end of the winter season, and the latter to the end of the summer season, does not disprove our conclusions and even makes them more convincing. As it is known from the observations in the region of frozen grounds, the range of temperature fluctuations in grounds is growing narrower with depth. The depth it is found to decrease varies in different regions, depending upon local conditions. Thus, for example, at Bomnak, in the upper parts of the Zeya river, temperature fluctuations start damping from a depth of 5 m; at Skovorodino, on the former Amur railway, from 10 to 12 m; at Anadyr in the Chukotka, from 14 to 15 m, and so on. For the Old-Turukhansk region it may be presumed, by way of analogy (for lack of prolonged observations), that damping begins at a depth of no more than 10—13 m.

Taking the lag of heat penetration from the surface to a 10-m depth to range within 4—6 months, we may consider the temperatures recorded at 10, 13 and even 15-m depth to characterize the heat wave of the very beginning of the summer season and have thus to suppose a further increase of temperature at the same depths, while the temperatures recorded by Middendorff characterize rather the beginning of the winter period, and more considerable cooling of the grounds could be expected within the following months. It means that a comparison of Middendorff's temperatures with ours, reduced to the same season, will show a still greater deviation of temperature curve obtained by us. At any rate, at a depth of 8—12—15 m the range of fluctuations of winter and summer temperatures for the given area would hardly exceed 0.1—0.2°C, whereas the difference obtained equals 0.3—0.4°C. In other words, taking into account the data obtained and the aforesaid considerations, we have in 1937 an unmistakable rise of the temperature of grounds at equal depths as compared to 1843, or the subsidence of the upper limit of the surface of frozen grounds. In such a manner, from Middendorff's observations and our repeated investigations it may be stated that for the period of about a century the boundary of frozen grounds has considerably receded which no doubt signifies the retreat of frozen grounds in the region of Old-Turukhansk. This once more confirms the fact of degradation of frozen grounds in Western Siberia, similar to that discovered in the Far Eastern region by Soumgin, on the basis of the materials of the Frozen Grounds Station at Skovorodino.

There is still one curious fact worthy of consideration. In all three points, where repeated boring was performed, frozen grounds extended at great depths (the latter have not been reached by us). Neverthelless in our additional borings and soundings in the vicinity of Old-Turukhansk, frozen grounds were found at depths of 1.2—1.5 m only. Among them some lying on the terrace shelves of southern exposure, being there disadvantageously situated with regard to insolation and drainage. In such places bore-holes drilled to a depth of 6—7 m did not penetrate any stratum of frozen grounds. This anomaly in the distribution of the upper surface of frozen grounds at Old-Turukhansk was not recorded by Middendorff. However, according to our observations, in other districts of the Turukhansk region (trading settlement Farkovo, at a distance of 120 km from Old-Turukhansk) such an «anomalous» distribution of the upper surface of frozen grounds is a rule. In many places we have established the presence of frozen grounds close to the diurnal surface, while at the same time in adjacent localities (20—30 m away) the surface of the frozen grounds occurred only at a relatively great depth (10—12 m). This fact is characteristic for the zone near the southern margin of the frozen grounds region both in the Asiatic and the European

part of the USSR and depends to a great extent on local conditions of each individual area.

Quite an unexpected phenomenon was discovered in the process of drilling at the town of Old-Turukhansk—the suction of atmospheric air into the bore-hole which was manifest for two days in the 3rd bore-hole, at a depth of 10 m from the surface. The suction was so intense that the bore-hole produced a noise audible at a distance of 25—30 m. The analysis of this phenomenon led us to the conclusion that we struck an isolated barred layer (of sand) with rarefied atmosphere. There were no visible traces of the karst type disclosed on the site. This could have rather been formed as a result of the melting of ice, of intermittent ice-layers and ice-cement in the heart of sedimentary rocks, isolated from below by frozen grounds and from above by a dense impenetrable stratum (clay bands) and inaccessible to the air from outside. As a result of ice melting, the volume of voids grew, and owing to the isolated position of this layer a vacuum was formed. On account of this peculiar phenomenon the bore-hole was put out of work and precautions were taken that this layer should again be isolated from atmospheric air as soon as the drilling ceases.

This fact, as we see it, is a further proof of the degradation and retreat of the frozen grounds in the region of Old-Turukhansk and apparently of a retreat which may be considered rather intensive in the geological sense.

While closing our brief communication, we should like to recall the fact, that in addition to the theoretical conclusions derived by Soumgin, a number of other investigators have pointed out the fact of the retreat of frozen grounds in other parts of the USSR. Thus, for instance, the expedition of the former Committee for the Investigation of Frozen Grounds in 1933 did not discover any frozen grounds in the vicinity of the town of Mezen, although they had been recorded as existing there by Shrenck in the first half of the past century. In the following year, i. e. in 1934, the same was observed in the region of Petchorsk, in the district of Ust-Us. Subsequently, in 1935 the author of this article observed signs of degradation of frozen grounds in the Anadyr district of the Tchukotsk region. In 1936 Soumgin reported the same fact with regard to the Kola peninsula. In 1937, as brought forth in this article, we made similar observations at Turukhansk. Analogous data have been obtained also by other investigators. Thus, each year furnishes new proofs regarding the retreat of frozen grounds occurring under natural conditions.

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HYDRODYNAMIQUE

SUR LE MOUVEMENT D'UN LIQUIDE LOURD DANS UN CANAL AYANT UN FOND AVEC UNE MARCHE

Par N. E. KOTCHIN

(Présenté par S. I. Wawilow, de l'Académie, le 16. IV. 1938)

Examinons le problème plan sur le mouvement irrotationnel d'un liquide homogène lourd incompressible dans un canal, dont le fond $ABCD$ a une marche BC de la hauteur 2ε. En orientant l'axe Ox horizontalement et l'axe Oy verticalement (de bas en haut) nous allons avoir sur la partie AB horizontale du fond, s'étendant à l'infini dans le sens des x négatifs, l'égalité $y = +\varepsilon$. Sur la partie verticale BC du fond nous aurons l'égalité $x = 0$. Enfin sur la partie horizontale CD du fond s'étendant à l'infini dans le sens des $x > 0$, nous aurons $y = -\varepsilon$.

Désignons la surface libre du liquide par EF.

Supposons que le liquide se déplace dans le sens des $x > 0$, la vitesse c et la profondeur $(h - \varepsilon)$ du liquide non troublé pour $x = -\infty$ étant données.

La présence de la marche sur le fond causera un trouble dans le mouvement du liquide. Déterminons ce trouble, ainsi que la forme de la surface libre du liquide, en négligeant le carré de la grandeur $\frac{\varepsilon}{h}$, supposée petite.

À la region du courant dans le plan du potentiel complexe $w = \varphi + i\psi$ correspond une bande $0 < \psi < q$ limitée par les droites $A'B'C'D'$ et $E'F'$; le point B' pour lequel $\varphi = -a$, $\psi = 0$, correspond au point B du fond, de même que le point C' dont les coordonnées sont $\varphi = +a$, $\psi = 0$ correspond au point C.

Il est évident que la grandeur a est de l'ordre de $c\varepsilon$.

Il suit de l'intégrale de Bernoulli, que l'on a sur la surface libre l'égalité:

$$gy + \frac{1}{2}\left|\frac{dw}{dz}\right|^2 = gh + \frac{1}{2}c^2.$$

D'où, en négligeant les valeurs du second ordre $\left(\frac{\varepsilon}{h}\right)^2$, en raison de leur petitesse, on obtient pour $\psi = q$ l'égalité:

$$g(y - h) = c^3 Re\left(\frac{dz}{dw} - \frac{1}{c}\right). \qquad (1)$$

En posant

$$\frac{g}{c^2}=\nu,\quad \frac{dz}{dw}=\frac{1}{c}\sqrt{\frac{w+a}{w-a}}\left\{1+a\Omega\right\},\qquad (2)$$

on trouve facilement que la fonction $\Omega(w)$ doit être holomorphe dans la bande $0<\psi<q$, et doit satisfaire aux conditions $Im\,\Omega=0$, pour $\psi=0$, et

$$Re\left\{\sqrt{\frac{w+a}{w-a}}\left[a\frac{d\Omega}{dw}-\frac{a^2\Omega}{w^2-a^2}-\frac{a}{w^2-a^2}+i\nu(1+a\Omega)\right]\right\}=0$$

pour $\psi=q$.

En négligeant de nouveau les grandeurs du second ordre, on trouve la condition

$$Re\left\{\frac{d\Omega}{dw}+i\nu\Omega+\frac{i\nu}{w}-\frac{1}{w^2}\right\}=0\qquad (3)$$

pour $\psi=q$.

Pour satisfaire à la condition $Im\Omega=0$ pour $\psi=0$ posons

$$\Omega(w)=\int_0^\infty\left(A(\lambda)e^{i\lambda w}+\overline{A(\lambda)}e^{-i\lambda w}\right)d\lambda+A_0,$$

où A_0 est une constante réelle, $A(\lambda)$ — une fonction pour l'instant inconnue, $\overline{A(\lambda)}$ — une quantité qui lui est complexement conjuguée.

Comme l'on a

$$\frac{1}{w}=-i\int_0^\infty e^{i\lambda w}d\lambda\qquad (4)$$

pour $\psi>0$, et

$$Re\int_0^\infty B(\lambda)e^{-i\lambda w}d\lambda=Re\int_0^\infty\overline{B(\lambda)}e^{2\lambda q}e^{i\lambda w}d\lambda$$

pour $\psi=q$, il est facile de déduire de (3) qu'il est nécessaire de poser

$$A(\lambda)=\frac{i(\lambda+\nu)e^{-\lambda q}}{2\Theta(\lambda)}$$

où

$$\Theta(\lambda)=\lambda\,\mathrm{ch}\,\lambda q-\nu\,\mathrm{sh}\,\lambda q.\qquad (5)$$

On trouve ainsi

$$\Omega(w)=-\int_0^\infty\frac{(\lambda+\nu)e^{-\lambda q}\sin\lambda w}{\Theta(\lambda)}d\lambda+A_0.$$

Si l'on a $\nu q\gg 1$, l'équation $\Theta(\lambda)=0$ admet une racine positive λ_0. Dans ce cas il faut considérer la valeur principale de l'intégrale; de plus, dans ce cas, dans l'expression de $\Omega(w)$ il faudra introduire les termes supplémentaires, déterminant les ondes libres:

$$\Omega(w)=-\mathrm{v.\,p.}\int_0^\infty\frac{(\lambda+\nu)e^{-\lambda q}\sin\lambda w}{\Theta(\lambda)}d\lambda+A_0+Ce^{i\lambda_0 w}+\overline{C}e^{-i\lambda_0 w},\qquad (6)$$

où C — est une constante complexe arbitraire.

On détermine cette constante, ainsi que la constante A_0, de la condition que la vitesse prend une valeur donnée lorsque $x \to -\infty$. Cette condition nous donne

$$\lim_{\varphi \to -\infty} \Omega(w) = 0.$$

Mais on peut établir qu'on a

$$\lim_{\varphi \to \pm\infty} \left\{ \text{v. p.} \int_0^\infty \frac{(\lambda+\nu)\, e^{-\lambda q} \sin \lambda w}{\Theta(\lambda)}\, d\lambda \pm \right.$$

$$\left. \pm \frac{\pi}{2} \left[\frac{(\nu-\lambda_0)\, e^{\lambda_0 q}}{\Theta'(\lambda_0)}\, e^{i\lambda_0 w} + \frac{(\nu+\lambda_0)\, e^{-\lambda_0 q}}{\Theta'(\lambda_0)}\, e^{-i\lambda_0 w} + \frac{\nu}{1-\nu q} \right] \right\} = 0.$$

Pour cela il faut prendre

$$A_0 = -\frac{\pi\nu}{2(1-\nu q)}, \quad C = -\frac{\pi}{2} \frac{(\nu+\lambda_0)\, e^{-\lambda_0 q}}{\Theta'(\lambda_0)}. \tag{7}$$

La valeur de la constante q est

$$q = c(h-\varepsilon). \tag{8}$$

Ayant déterminé Ω, nous trouverons

$$z = -i\varepsilon + \int_a^w \frac{1}{c} \sqrt{\frac{w+a}{w-a}} \left\{ 1 + a\Omega(w) \right\} dw, \tag{9}$$

en intégrant l'égalité (2) et en notant que pour $w = a$ on a $z = -i\varepsilon$.

D'où, en posant $w = -a$, $z = i\varepsilon$, on trouve dans la première approximation la valeur de a:

$$a = \frac{2c\varepsilon}{\pi}. \tag{10}$$

Arrêtons nous encore sur la détermination de la forme de la surface libre. La formule (1) permet d'écrire:

$$y = h + \frac{a}{\nu c} Re \left\{ \frac{1}{\varphi + iq} + \Omega(\varphi + iq) \right\}.$$

En utilisant les formules précédentes nous obtenons:

$$y = h + \frac{a}{\nu c} \left\{ A_0 + 2C \operatorname{ch}(\lambda_0 q) \cos \lambda_0 \varphi - \text{v. p.} \int_{-\infty}^{+\infty} \frac{\nu e^{i\lambda\varphi}}{2i\Theta(\lambda)}\, d\lambda \right\}. \tag{11}$$

En désignant les racines complexes de l'équation $\Theta(\lambda) = 0$ par $\pm i\mu_k$, où $0 < \mu_1 < \mu_2 < \ldots$, on pourra écrire l'expression précédente

$$\left.\begin{aligned} y &= h + 2\varepsilon \sum_{k=1}^{\infty} \frac{e^{\mu_k \varphi}}{\Theta'(i\mu_k)} && \text{pour } \varphi < 0. \\ y &= h - 2\varepsilon \sum_{k=1}^{\infty} \frac{e^{-\mu_k \varphi}}{\Theta'(i\mu_k)} - \frac{2\varepsilon}{1-\nu q} - \frac{4\varepsilon}{\Theta'(\lambda_0)} \cos \lambda_0 \varphi && \text{pour } \varphi > 0. \end{aligned}\right\} \tag{12}$$

Si $\nu q < 1$, c'est-à-dire $gh < c^2$, l'équation $\Theta(\lambda) = 0$ n'a pas de racines réelles différentes de zéro, et par suite le dernier terme dans l'expression de y pour $\varphi > 0$ manque.

Dans ce cas il ne se forme pas d'ondes et le profil de la surface libre

baisse de la grandeur $\frac{2\varepsilon}{1-\nu q}$ plus grande que la grandeur de la marche au fond.

Si $\nu q > 1$, c'est-à-dire $gh > c^2$, il se forme des ondes, dont l'amplitude est $\frac{4\varepsilon}{\theta'(\lambda_n)}$.

Le niveau général de l'eau dans ce cas monte. Wien [1], en examinant le même problème, a obtenu pour l'amplitude des ondes formées une valeur inexacte, à savoir, deux fois plus petite.

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ASTRONOMIE

ASTROPHYSIQUE AU PÔLE NORD

Par B. G. FESSENKOFF, de l'Académie

Le pôle nord rendu accessible grâce aux remarquables travaux des savants soviétiques n'est pas en général une place appropriée pour les recherches astronomiques. Néanmoins il en existe quelques problèmes astrophysiques qui peuvent être résolus en préférence aux environs du pôle.

Tel est le problème de l'ozone atmosphérique. Tout conduit à penser que l'ozone s'est produit dans les hautes couches atmosphériques en conséquence des réactions photochimiques sous l'action des rayons ultraviolets du soleil. Il est très important de savoir comment se conduit la couche équivalente de l'ozone pendant la nuit polaire dans la région du pôle où l'observateur est éloigné des parties atmosphériques éclairées par le soleil. Les observations de ce genre peuvent être effectuées à l'aide d'une chambre prismatique à quartz guidée par une lunette à monture équatoriale, comme cela était pratiqué par M. D. Chalonge et ses collaborateurs. Il est intéressant aussi d'observer dans les régions près du pôle la luminosité du ciel nocturne. Les causes de la luminosité nocturne ne sont pas entièrement connues, surtout de la luminosité de la partie continue du spectre. On sait qu'en lumière photographique cette luminosité varie jusqu'a 300% et même davantage, étant cependant beaucoup plus constante en lumière visuelle.

La radiation monochromatique, la plus étudiée dans le spectre du ciel nocturne, notamment la raie 5577, qui accuse la variation assez régulière pendant la nuit avec maximum peu après la minuit et dont la nature atomique est bien connue, est due à ce qu'il paraît aussi à l'action de la lumière ultraviolette du soleil. Par conséquent il est désirable de pouvoir suivre la variation de cette raie pendant la nuit polaire pour les mêmes raisons que pour l'ozone atmosphérique.

En ce qui concerne la composante continue de la luminosité nocturne il est essentiel de la comparer avec les valeurs analogues obtenues sous des latitudes basses. La variation de cette composante observée dans les conditions sensiblement identiques peut d'ailleurs être facilement liée avec les nombres charactéristiques du soleil. Les observations photométriques correspondantes peuvent être assurées facilement avec un photomètre tubulaire automatique pour la lumière photographique et avec un photomètre radioactif à échelons pour la lumière visuelle.

Le même photomètre visuel qui est extrêmement portatif peut être employé pour l'étude de la lumière zodiacale. Au pôle nord le phénomène de la lumière zodiacale est toujours accessible pour les observations pourvu que le ciel soit suffisamment obscur. Contrairement à ce qu'on voit sous

de basses latitudes la lumière zodiacale près du pôle géographique apparaît comme une large bande lumineuse qui se propage toujours près de l'horizon, ses deux branches—l'occidentale et l'orientale—étant visibles simultanément. Dans ces conditions l'intérêt scientifique que présente ce phénomène provient du fait qu'il est dû principalement à l'ensemble de la matière météorique provenant des régions galactiques et par conséquent étrangère à notre système solaire. La densité du milieu interplanétaire, rempli par cette matière, ne peut pas être constante. En conséquence de l'action perturbatrice du soleil la densité doit être sensiblement plus considérable dans la direction de la propagation du courant météorique que dans les autres directions. Aussi comme on peut s'y attendre les deux branches de la lumière zodiacale doivent être en général différentes l'une par rapport à l'autre et cette différence doit s'accentuer selon les positions de la terre sur son orbite.

L'inhomogénéité du courant passant par le système solaire se traduit évidemment par les irrégularités des isophotes de la lumière zodiacale. Il est évident que les observations photométriques de ce genre sont importantes pour la théorie de ce phénomène.

Il est enfin à remarquer que le nombre d'étoiles filantes, comptées á l'aide d'une lunette à grand champs de vue ou bien à l'oeil, peut donner des indications supplémentaires sur la densité de la matière interstellaire dans les régions pratiquement inexplorées de l'espace, et cela d'autant plus facilement que sur le pôle géographique l'effet diurne bien connu est totalement absent.

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PHYSICAL GEOGRAPHY

MAIN PHYSICO-GEOGRAPHICAL FEATURES OF LAND IN THE ARCTIC BELT

By A. A. GRIGOREV

(Communicated by O. J. Schmidt, Member of the Academy, 16. V. 1938)

The most characteristic peculiarity of the physico-geographic conditions in the Arctic consists in a combination of very low temperatures throughout the year with a sharply negative annual balance of radiant energy near the earth surface and a positive balance of water in its solid phase, such conditions continuing either during the whole year or during its major portion; with precipitation in the form of snow being available—be this but to a small extent—even in the warmest summer months. The first combination of such conditions is observable (at sea level) in such places where the mean temperature of the warmest month lies below 0°; while the second combination prevails where this mean temperature is above 0° but below 5° C. Accordingly, it is customary to divide the Arctic belt of both hemispheres into two zones: that of the higher Arctic and that of the outer Arctic zone. The outer boundary of the first zone in non-mountainous regions is formed by the 0° combined isotherm of the warmest month; while the boundary of the second is constituted by the 5° isotherm. The mountainous regions contained within the mentioned limits have of course distinct features of their own and must be considered as the mountain variants of the basic type of the geographical medium of the respective zone. However, the high Arctic zone essentially consists of such mountainous territories of the whole Antarctic. In the north hemisphere, where the high latitudes are occupied by the sea, this zone is not represented on dry land.

The following land belongs to the outer Arctic zone: the Spitzbergen Archipelago, Franz Joseph Land, the greater part of the Northern Island of Novaya Zemlya, Northern Land, the New-Siberian Archipelago, Wrangel Island, the Northern belt of Taimyr, a narrow strip of the mainland to the east of Tchaunsskaya Guba, the greater part of the North-American Arctic Archipelago (except the southern and eastern part of Baffin Land, etc.), the Melville and Boothia peninsulas, a part of the mainland near Point Barrow, a large part of Greenland in the region of the ice-shield and the whole littoral part of Greenland free of ice to the north of 69° lat. to the east and 73° to the west. In the southern hemisphere only small islets are found to belong to this zone.

On account of a very great summer insolation during the «polar day» and the tremendous rôle of diffuse radiation the differences in the summer temperatures of both zones depend solely and exclusively upon the

magnitude of the expenditure part of the balance of radiant energy. The main items on the expenditure side are the losses due to reflection and melting of the ice-snow cover. Accordingly where the latter is so thick that it is retained during the whole summer, the mean summer temperatures are characterized by the minus sign. On the other hand, in such places where the ice-snow cover has time to melt and where heat is expended mainly on thawing the soil and evaporation, the outlay of heat is somewhat less and the mean monthly temperatures are characterized by the plus sign. Thus, in the final account, the temperatures of summer months depend on the thickness of the ice-snow cover accumulated during the remaining months, while this thickness is, in its turn, determined by the amount of precipitation (excepting the regions where ice descends from elevated spots). As to the amount of precipitation, this depends in first place upon the character of atmospheric circulation, since relative humidity is very high, reaching 80% as a minimum; in the Antarctic, in terms of ice, it surpasses 100%. The temperature inversion, sharply marked above snow and ice bound land and sea, causes comparatively high temperature at an elevation of several hundred meters and more which provides for a relatively considerable absolute humidity here, at the same time creating (with corresponding motion of the atmosphere) conditions which are most favourable for the condensation of vapours and precipitation. According to the data of Bird's expedition in the region of Ross's Barrier (78°30′ southern lat.), the pressure gradient, up to an altitude of 3000 m, runs northward, while it is directed towards the south at greater elevations; the direction of the winds is changed respectively. Therefore those parts of the Antarctic which are located at an altitude of 3000 m or more should, in their greater part, be under the direct influence of the cyclonic system of atmospheric motion, accompanied by precipitation. According to Meynardus, the latter conditions begin to prevail at an altitude of 2000 m. The same is very often observable above the ice-shield of Greenland, in the centre of which about 315 mm precipitation is available, according to the data of Wegener's expedition. Outside the cyclonic region in the Antarctic and in Greenland there are to be found accumulations of air which have descended from the upper portions of glaciers where anticyclonic conditions prevail. This air tends to form rings encircling the above-mentioned elevated regions, these rings having, as should be noted, a lower altitude than the summits they lie around. These high pressure rings are, however, well expressed only when the atmosphere is, on the whole, calm, whereas, when the atmosphere is disturbed, the regions in question are frequently seized by cyclones, which arrive from the temperate belt and are accompanied by precipitation. The lower the latitudes, which the ice-shields pervade, the more frequent will be these cyclones. The distribution of land and sea in the Northern Arctic belt is such, that, although a northwardly directed gradient of pressure is to be observed at an altitude of more than 1700 m, yet, the amount of air brought to the pole in winter and at the end of autumn is considerably weakened by the availability of sharp pressure maxima in Northern Asia and North America, where part of the air from higher layers is bound to descend. On the other hand, air above the Polar basin can never be cooled to such an extent as this is observable above the ice-shields covering land, since a large amount of heat penetrates from below, through the marine ice. All this prevents the formation of stable pressure maxima above the central portions of the Polar basin; wherefore the cyclones of the temperate belt can easily penetrate here without meeting with any particular obstacles on their way, as it has been first demonstrated by the investigations made at the North Pole Station. It is only in spring that both the mentioned factors become less effective, wherefore pressure is on

the whole higher and cyclones become less frequent visitors. On the whole, cyclones visit the American territories of the Arctic belt as well as the Asiatic ones from Taimyr to the east more rarely in the non-summer months; wherefore these parts of the Arctic have a more continental climate (there is less precipitation).

Thus, it may be said that land in the high-Arctic belt is characterized by a definitely negative heat balance during all the seasons combined with pronounced cyclonic, i. e. ascending, movements of the atmosphere, in other words, with a negative balance of gravitation in the lower layers of the atmosphere. It is this contradictory combination which causes a positive balance of ice and a sharply marked negative balance of water in the liquid phase; and it is again this combination which is apt to exclude from the physico-geographical process as a whole not only the biological and soil components, but also all the other processes usually connected with the activity of running water. Thus, the physico-geographical process appears to be, as it were, one-sided and, if we are to dismiss the phenomena taking place in the atmosphere, it is found to consist mainly in the formation of an ice-shield, of various types of glaciers, and also of shelf ice; all these formations reacting upon the lithosphere. The mentioned processes proceed on the whole very slowly. In result, a typical ice desert is formed, outwardly altogether different from the hot desert expanses of the trade-wind-swept tropics, but virtually analogous to these barren tracts of land in the presence of this very one-sided trend, as well as in the slowness of the physico-geographical processes involved. But perhaps the greatest analogy lies in both types of country being characterized by contradictory heat and gravitation balances in the lower layers of the atmosphere, although in the tropics the contradiction assumes a somewhat different character*. We shall not dwell here upon such small regions on the Antarctic shores which owing to specifically local conditions become entirely free of snow during the summer months. If the mean temperatures of the summer at the very earth surface are higher than 0°, the physico-geographical process runs here the same course as in the outer Arctic belt of which these exceptional regions may be considered to be the first outposts.

In the outer Arctic zone the above-described conditions prevail in a much weaker form during about ten months. Within the remaining two, or, more seldom, one or three months, the heat balance (near the surface of the earth) becomes positive (though to an insignificant extent); however, at a depth of 0.2—1.3 m it becomes negative , wherefore frozen grounds here attain rather considerable depths (on Spitzbergen down to 320 m), which prevents the development of any kind of geographical processes in the regions in question. The positive balance of heat in the lower layer of the atmosphere is the higher, the lower is precipitation in the cold months (cf. above). The presence of a waterproof frozen layer together with poor evaporation of moisture provides for sufficient humidity in the upper layer which is watered by snow and ice melting away. More or less considerable summer showers involve excessive accumulation of water (sharply positive balance) in the layer thawed through; this leads to the formation of marshes or else turns the surface layers into the flux soils. Both conditions are of course highly unfavourable for the intensive growth of vegetation. Accordingly, appreciable growth of vegetation is observable only within limited areas on soils that have a but small moisture absorbing capacity; or else on

* In the trade-wind tropic belts a positive balance of heat is accompanied by such atmospheric movements which have a descending resultant, i. e. with a positive gravitation balance in the lower layers of the atmosphere.

areas with good drainage (of course if the land is not exclusively pebble). Other areas are practically devoid of any vegetation whatever. We also find here strongly developed mechanical weathering of rocks as well as the formation of peculiar «structural» grounds (stone rings, meshes or bands) observable on heavy stony grounds, or else we see here the formation of «polygonal» soils available on clayey grounds capable of readily absorbing moisture. Coupled with this, owing to the absence of drainage for ground waters, salt crusts and flowerings will be formed on rocks containing large amounts of soluble salts; these are, however, apt to disappear after rain. Under the surface layers overgrown with vegetation thick podzol or peat soils are developed. The less precipitation there is, the drier is the climate and the more spread will be on the above-mentioned grounds growths of various Arctic half-shrubs and grasses, usually intergrown with moss. Moss marshes develop very slowly. The development of the mentioned kinds of vegetation and of the soils which underlie them is possible here only owing to the fact that the temperature of the soil and of the vegetable cover, due to insolation, is much higher than the temperature of the outer air.

Rather numerous animals find their habitat on the ground covered with the above-described vegetation. Among them we find such big herbivorous animals as the musk ox and reindeer. The number of these animals is the greater, the less thick is the layer of snow from under which they have to dig out their food. Thus, the less is the amount of precipitation with given temperatures not only in winter, but also in summer (i. e. the weaker the cyclones are expressed, or in other words, the less is the negative balance of gravitation in the atmosphere), the more intensive and the fuller becomes the development of the physico-geographical process in the outer Arctic zone. In the opposite case, it assumes the tendency of one-sided development and, outside of purely climatic processes, becomes mainly reduced to hydro-geomorphological processes, the freezing of the ground appreciably handicapping the development of rivers and the definite separation of water sheds. Thus, here, just as in the higher Arctic zone, the stronger is the contradiction between the negative annual balance of heat (with a weakly negative summer balance), on the one hand, and the ascending movements of the atmosphere, on the other hand, i. e. the negative balance of gravitation in the lower layers of the atmosphere, the weaker and the more one-sided is the physico-geographical process. It is clear that the weaker will be this contradiction, the more intensively this process will proceed.

We have seen that in respect of the main contradictions of the system of balances and also with reference to the intensity and the general trend of the physico-geographical process, it is possible to trace a definite analogy between the high Arctic and the outer (trade-wind-swept) zone of the tropics. The same may be said about the outer Arctic zone. The difference lies only in that, whereas, in the first case, it is necessary to make comparisons only with those provinces of the outer tropic zone where its specific features are expressed with particular prominence, in the second case comparison has to be made with those provinces where these peculiarities are expressed to a smaller extent.

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GEOLOGY

THE PRINCIPAL FEATURES OF THE TECTONICS OF THE NORTHERN PART OF THE ATLANTIC OCEAN AND ARCTIC

By A. D. ARKHANGELSKY, Member of the Academy

Geological investigations carried out during the last 10—15 years in the Arctic regions compell us to thoroughly review the current ideas as to tectonics of the Arctic and the northern parts of the Atlantic Ocean, and do this on the base of the to-date knowledge acquired by the recent studies of geological structure of the USSR (1) which have brought essential changes to our conceptions of the principal regularities in the development of the earth's crust.

According to the prevailing views which have been reflected also in the recently published tectonic schemes by Stille (2), Holtedal (3), Shatsky (4) and others, the northern part of the Atlantic Ocean is located in the place of a huge pre-Cambrian block (Eria) that subsided and had formerly constituted a single whole with the Canadian pre-Cambrian shield and formed with it the pre-Cambrian block of the Laurentia.

Quite different is the opinion concerning the Atlantic Ocean held by L. Kober (5) who considers that its median bank, together with the islands located on it, is a folded formation of Alpine age.

The problem of the tectonics of the Arctic is solved differently by different geologists. According to Stille, in the region of the Arctic Ocean folded formations of different age come together. As far as here run the bands of Caledonian foldings from England and Norway through Spitzbergen and the northern marginal part of Greenland from one side, and from the lower course of the Yenissei and the Taimyr peninsula, on the other. Here too we find wide bands of Hercynian folded formations coming from the area of the Urals and the West Siberian lowlands, as well as from the western part of the Chukotka peninsula. Finally, a wide band of Alpine folds, cutting off all the older folded structures, stretches to the Arctic from the region of the Verkhoyansk range and the basins of the Yana and Indihirka rivers, through the North pole, towards the northern marginal part of the Ellesmere land and Greenland. A scheme of the tectonics of the Arctic, closely approaching to the one described, is given by Shatsky. A study of the most recent Soviet material enabled him to expunge in the scheme of Stille the belts of caledonides of the lower course of the Yenissei and of Taimyr peninsula and of hercynides of the Chukotka peninsula; Shatsky presumes moreover that in the area of De-Long islands and the adjacent parts of the Arctic Ocean there is located the old Hyperborean pre-Cambrian massif, which seems to be a continuation of the Canadian shield. A still greater part in the Arctic

is assigned to folded structures of Alpine age by Kober, who not only believes the Verkhoyansk folded band to continue up to the region of the Arctic Ocean, but assumes that here continues also the young folded zone of the bottom of the Atlantic; Kober refers to this zone not only Iceland, but Spitzbergen too.

Quite different is the picture of the geological structure of the region of the Northern Atlantic Ocean, Greenland and Norwegian Seas in the light of the recent geological investigation.

The studies of Danish and Norwegian geologists, of which an excellent review has been given by L. Koch (6), have established that the Caledonian folding encircles the Greenland pre-Cambrian massif not only from the north, but from the east too. It is beyond any doubt, as pointed out also by Koch, that the caledonides of Eastern Greenland continue southward, into the folded structures of the system of Appalachian Mountains (Newfoundland, Nova Scotia, Piedmont plateau).

Thus, the folded structures of Caledonian age exist on the two coasts of the Atlantic Ocean and the depression of the Greenland and Norwegian Seas. Therefore, it is out of the question to assume that the outcrops of the pre-Cambrian rocks in the north-west of Scotland and on the Hebrides are a continuation of the pre-Cambrian Canadian shield. The massif of Eria, to which these exposures are assigned, may be considered as a special pre-Cambrian block, a kind of median mass located within a vast geosynclinal region, from which the European and American branches of caledonides have arisen.

Thus, we arrive at the conclusion that the North Atlantic Ocean with the Greenland and Norwegian Seas is located at the place of the old Caledonian geosynclinal region and its median pre-Cambrian massifs, from which at present only narrow marginal zones have been preserved. Giving due consideration to the structure of the caledonides of Greenland and Spitzbergen, with which we become acquainted from the papers by Frebold (7) and Koch (6), the conclusion may be reached that in this geosynclinal region tectonic movements in the form of faults and local folding occurred repeatedly also in the post-Caledonian time, up to the Tertiary time.

The conceptions of the tectonic structure of the region of the Arctic Ocean should at present be essentially altered too.

The hypothesis which supposed the region from the Verkhoyansk margin to the Ellesmere land to be crossed by a belt of folded structures of the Alpine system, was based on the presence of strongly dislocated Triassic rocks in the United States Mountains on the Grant land. Indications pointing to these young dislocations in the literature on tectonics were given as early as 1909 by Suess (8) and up to now they have been accepted by the authors of synoptic treatises on tectonics without due criticism and verification. On the other hand, C. Schuchert had pointed out in his article on the geosynclines of North America (9) that the folding on Grant land cannot be younger than the Upper Carboniferous, and that the Triassic rocks have not been affected thereby. In a recent synopsis by Koch we find the Caledonian age of this folding quite definitely established, since the Devonian, developed on the northern coast of the Ellesmere land, do not take any part in this folding.

Thus, data supporting the existence of folded structures of the Alpine system in the Polar basin area are lacking, and this assumption should be discarded. The Mesozoic and Tertiary folding of north-eastern Asia and north-western America does not continue to the pole but is confined to the periphery of the Pacific Ocean. On the contrary, the strikes of the Mesozoic folding both in America and in Asia, as well as the turn of the Hercy-

nian folds to the north on Northern land, suggest the existence of an old, probably, pre-Cambrian steady massif in the region of the Arctic Ocean. According to Schuchert, to this massif may belong the exposures of old rocks on the north coast of Ellesmere land and the pre-Cambrian platform of De-Long islands, mentioned by Shatsky. A junction of this massif, named Pearya by Schuchert and Hyperborean by Shatsky, with the Canadian shield is hardly probable, since they must be divided by Caledonian folded structures formed in the North Greenland or, according to Schuchert, Franklinic geosynclinal area.

The last point that should be mentioned here is the question as to how far northward to the Arctic does the East European or Russian platform extend. In solving this problem it is in the first place necessary to consider the indication of Frebold that the Caledonian folding of Spitzbergen does not extend far eastward and that in the eastern part of the Northeastern land the old Paleozoic rocks lie almost horizontally. This justifies the assumption that the platform continues to the latitude of Spitzbergen in the shape of a wedge, which both here and further south divides the region of the Caledonian Atlantic and Hercynian Uralian folding. This assumption is in good agreement with the direction of the Hercynian folding on Novaya Zemlya.

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PALEOGEOGRAPHY

PRINCIPAL POINTS IN EVOLUTION OF PHYSICO-GEOGRAPHICAL CONDITIONS THAT WERE PREVAILING IN CENTRAL DEPRESSION OF KAMCHATKA DURING THE QUATERNARY

By S. L. KUSHEV and J. A. LIVEROVSKY

(Communicated by A. A. Borissiak, Member of the Academy, 4. IV. 1938)

For two years (1935—1936) the authors of the present paper carried on a geomorphological investigation of the Central depression of Kamchatka and the valley of Kamchatka river.

The Central depression of Kamchatka was during a long period of time the region where mellow clastic and pyroclastic deposits were accumulating. The geomorphological investigation of the depression enable us not only to throw light upon the history of the development of the relief, but also to trace change of the physico-geographical conditions which were prevailing there during the Quaternary.

The first geographical and geological data embracing both the valley of the river and the peninsula in whole have been due to the works of Krasheninnikov (4), Ermann (9), Ditmar (1), Bogdanowitsch (8), and Sliunin (7). The pre-revolutionary period of investigation of Kamchatka ended with the expedition of F. P. Ryabushinsky, the transactions of which [papers by V. L. Komarov (3), Kell and Konradi (2), etc.] gave new information in the geology of the peninsula, particularly referring to the Quaternary. The Soviet period begun in 1923 with the organization of extensive systematic investigations of Kamchatka.

All the above-mentioned works have considerably widened and made more precise knowledge of the geology and geography of Kamchatka; yet they were lacking definite data on the development of the relief and the Quaternary age history of the country. In result of fragmentary observations made by different authors the fact of the Quaternary glaciation of Kamchatka has been established beyond any doubt. The question as to the number and the extent of the glaciations remains as yet unsolved.

A study of the Quaternary deposits of the extensive territory of Kamchatka is not of merely regional importance, but it is a necessary link for a complete understanding of the events which took place during the Quaternary history of the whole north-eastern part of Asia; for this reason the present authors have tried to elucidate the Quaternary history of the Central Kamchatka depression with the utmost completeness.

The Central Kamchatka depression is located between the Sredinny Kamchatka range in the west and a group of volcanoes and mountain ranges in the east. It is filled in its central portion by lacustrine sediments: clays, sands, pebblestones and conglomerates, and at the peripheral portions, by glacial, fluvioglacial, proluvial and volcanic deposits.

The Kamchatka river valley passes through friable deposits, the total thickness of which is up to 120 m.

According to the character of its relief and that of the Kamchatka river valley, the Central Kamchatka depression may be subdivided into three geomorphological areas. The first area, from the upper portion of the Kamchatka river to the latitude of the village Verkhne-Kamchatsk, presents a narrow part of the depression with forms of glacial and fluvial accumulation developed here. In the narrow valley of Kamchatka river accumulative terraces 1 (I), 2—2.5 (II), 4.5 (III), 8 (IV) and 12 m (V) have been observed having a total (visible) thickness about 5 m.

The second area, from the latitude of the village Verkhne-Kamchatsk to the latitude of the village Sredne-Kamchatsk, is characterized by a widening of the depression up to 100 km and by a development of sculptural-accumulative forms of the relief. The valleys of the Kamchatka river and its tributaries have a sculptural character. The following levels of the terraces of the Kamchatka river have been observed here: 2—3 (I), 3—4 (II), 5—7 (III), 9—12 (IV), 18—22 (V), 35—40 (VI), 50—60 (VII), 70—80 (VIII) and 90—100 m (IX). Of these the lower four terraces are accumulative, the fifth terrace is mixtiform; and all the higher lying terraces are erosional, formed within the thickness of lacustrine sediments of the old Quaternary age.

The third area, from the latitude of the village Sredne-Kamchatsk to the latitude of the village Klyutchy, is characterized by a development of mainly accumulative forms of the relief formed by volcanic, glacial, erosional and proluvial processes. In the Kamchatka river valley the following terrace levels have been established: 1.5—3 (I), 3—3.5 (II), 4—6 (III), 9—13 (IV), 15—22 (V), 35—40 (VI), 50—60 (VII), 70—80 (VIII), 90—100 (IX), 130—140 (X) and 200 m (XI). The first and second terraces are accumulative, the third and fourth, mixtiform, and the above lying are erosional terraces.

The data available make it possible to mark the following principal moments in the history of the relief during the Tertiary and Quaternary.

Towards the close of the Tertiary and at the beginning of the Quaternary a mountainous northern basin of the temperate type existed within the Central Kamchatka depression. Bluish clays and greenish sands and sandy loams were depositing with a total (visible) thickness of about 5 m. The climate was temperate, appropriate for the growth of forest zone vegetation.

Fir-forests have been prevalent in the Central Kamchatka depression. The pollen of the fir constitutes 70—79% of the total pollen of trees in the sediments of the lacustrine basin. Spruce occupied a subordinate position in the fir-forests; its pollen constitutes 2—17% of the whole quantity of pollen of trees. The larch also constituted a trifling part, the content of its pollen varying from 1 to 2%. The percentage of the pollen of *Pinus pumila* is about the same.

The composition of diatomeae from the upper horizons of the deposits of the above lacustrine basin is characterized by a considerable development of species connected with an overgrowth and a certain diminuation of the plankton species. This circumstance shows that a certain change took place in the hydroglacial conditions of the basin, i. e. that the basin was getting shallower. The shallowing is, evidently, connected with a powerful uplift of the whole area, which happened at the time and caused an outflow of the waters of the lacustrine basin, which resulted in the final disappearance of the latter at the beginning of the post-Pliocene. Numerous vegetable remains including peat lenses, encountered in the deposits under investigation, clearly show the picture of a gradual shallowing of the basin. At the bottom of the basin an alluvial plain is formed, within which the ancient-Kamchatka river, probably, springs up.

The intensive volcanic activity, accompanied by effusions of basalt, which flows up to the centre of the depression, is referred to the moment of drying of the basin and of the formation of the alluvial plain.

The general uplift of the area has been accompanied by an extensive glaciation (the first glacial epoch) of the mountainous areas of the region. The glaciers moved up to the marginal parts of the depression, partially penetrating beyond its limits, and filled its southern narrow part. This maximum glaciation was of the Malaspin type. Coarse fragmental morainic débris have been deposited at this time within the depression, and pebblestones and sands in its extraglacial parts. A study of the present-day and fossil flora and fauna supports our conclusion that Kamchatka was not throughout covered with glaciers. As will be seen below, the woods of Kamchatka have outlived glaciation, though the latter considerably restricted the development of some of them, having produced peculiar, disrupted areals (the coniferous Kamchatka island).

During the subsequent warmer interglacial epoch a melting of the glaciers took place with a formation of an extensive lacustrine basin within the depression, where at the beginning coarser deposits have been accumulated: boulder-pebblestones, pebblestones and arenaceous, and later on more disperse sands and loams of a total thickness about 90 m.

The accumulation of deposits was taking place on the background of the general epeirogenic subsidence of the area, which corresponded to the post-Pliocene subsidence at the eastern and western shores of Kamchatka, and caused a transgression of the sea.

A study of the diatomeae of the interglacial lacustrine basin in the Central Kamchatka depression showed that their composition is characterized by northern and north-Alpian forms.

As compared to the pre-glacial lacustrine basin the interglacial basin is distinguished by a lesser depth and by rougher hydrothermal conditions.

During the glaciation trees considerably reduced the limits of their habitat. The rather rough climatic conditions have, probably, hindered their rapid expansion; for this reason the content of tree pollen in the deposits of the interglacial basin is insignificant: pollen of fir-trees almost completely disappears and only pollen of *Pinus pumila* increases abruptly; it occupies the second place after the fir (up to 14% of pollen). Buried remains of mammoths and primitive oxen, not encountered in younger deposits, have been found in the interglacial sediments.

During the subsequent second glacial epoch of the Quaternary a new uplift of the area took place, the lake became shallow, and its bottom got exposed as a flat plain. The rivers, flowing down the slopes of mountain ranges, surrounding the Central Kamchatka depression, unite to a single stream at its lower portion, forming the Kamchatka river.

While the region under investigation gradually rised, the Kamchatka river and its lateral tributaries divided the surface of the plain into a number of flat-topped uplifts, intersected the accumulated lacustrine sediments and formed there their own river valleys with a series of high erosional terraces, attaining 90—100, 70—80, 50—60 and 35—40 m of relative height.

The uplift of the whole region has been accompanied by an increase of the intensity of the glaciation phenomena of the mountainous regions surrounding the Central Kamchatka depression. This glaciation had a typical Alpian character; the glaciers were localized in small mountain valleys and did not penetrate the zone of the depression. Traces of this glaciation are clearly pronounced in the upper parts of mountain rivers—tributaries of the Kamchatka river—in the form of fresh kars, trough-valleys, slightly subjected to denudation and erosion, and so on. Traces of this last glaciation

have been reported by the investigators in the southern parts of Kamchatka. It should be noted, however, that we cannot speak definitely of independent glaciations, until interglacial sediments are found at the Kamchatka in their proper stratigraphic position. Possibly the two glaciations noted by us are two large phases of a single glaciation of the Central Kamchatka depression: in this case the deposits described above as interglacial should be regarded as interstadial.

During the post-glacial epoch a number of cyclic subsidences and uplifts of the area occurred resulting in a formation of 15—22, 9—12 and 5—7 m erosional-accumulative terraces of the Kamchatka river. During this epoch an abrupt change of climatic conditions towards warmth set in (the post-glacial climatic optimum) resulting in a considerable melting away of the glaciers in the mountainous parts of the region. The areal of wood vegetation became more extensive, fir and larch being chiefly encountered in the depression, and grassy birch-groves, in other parts of Kamchatka.

Actually the whole region was gradually raised and 3—4 and 1.5—3 m terraces of the Kamchatka river formed; this was attended by an intensive activity of the Kamchatka volcances which ejected lava and ashes. The latter settled over a considerable area of Kamchatka and in the northern part of the depression a 1—1.5 m thick layer of volcanic ashes covered almost all the forms of the relief.

In the mountainous areas of the region, especially on volcanoes, recent glaciers are developed, occasionally attaining 1.5 km in length. Recent glaciers are observed on the volcano-hills Shiveluch, Klyuchevskaya, Ploskaya, Zimina, Tolbachik, Zhupanovskaya, Koryakskaya, Avachinskaya, Kozelskaya, Asachinskaya, Mutnovskaya, Kambalnaya and Arik, and also at the summits of the Sredinny Kamchatka range (Khoa-Shen, White range), the Valagian range and in the Chazhmin basin. The yearly melting of the glaciers results in a formation of proluvial trains both at the slopes of the volcanoes and at the slopes of the Kamchatka river valley; the surface of these trains presents peculiar sandy landscapes.

When in comparing our scheme of the Quaternary of the Central Kamchatka depression with that of the geological history of the Far-East Region, China and Japan, worked out by Krishtofovich (5), we find that the principal epochs established by him and by the present authors are in agreement, while the characteristics of the physico-geographical conditions of some of the epochs is widely different. Thus, according to Krishtofovich the interglacial epoch was distinguished by a very warm climate, which favoured the development of subtropical vegetation (*Ginkgo*, *Zelkova*). Paleogeographic data on Kamchatka and Nizhny Amur show that the climatic conditions of this epoch differed very little from those of the present time. Moreover, the present authors establish for the Central Kamchatka depression a post-glacial climatic optimum which is absent in the scheme of Krishtofovich.

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MINERALOGY

GEOCHEMISTRY AND MINERALOGY OF POLAR REGIONS

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1. A definite latitudinal zonality has been established as early as in the classical schemes by V. V. Dokuchaev in the analysis of soil processes. This purely morphological division developed into the modern soil system, where the external features of soil are presented in their chemical aspect.

The zonality of chemical processes of the earth's surface and their connection with climatic zones formed the basis not only of the modern soil science, but also of the sedimentary geology and mineralogy (W. H. Twenhofel, O. Walter, L. Cayeux, K. Andrée, F. Clark, E. Blackwelder, etc.).

Up to the present, however, no one has advanced clearly enough the question as to the physico-chemical factors responsible for the striking difference which impresses anybody who would try to compare, say, the scale of colours of geochemical compounds from Murmansk in the north to Batumi in the south (1).

2. The chief factors accounting for the different course of geochemical processes at different latitudes are the fluctuations of temperature and the quantities of the liquid phase of water. The decrease of average temperatures to 0° and lower produces (according to a rule familiar in chemistry) a decrease of velocity of chemical reactions, which may, if the trend of the temperature curves is taken into account, reduce their rate 6—9 times, such coefficient being indeed very considerable. This results in a difference of the biochemical reactions at different latitudes too.

The second factor—humidity—is of no less importance. Its effect is, however, more complicated, since the course of the chemical reaction depends not on the total quantity of precipitations, but on their distribution, the value of relative humidity and the aggregate state of water. The relatively small quantity of liquid water and at times the decrease of the relative humidity of ascending currents approach the Polar regions to the region of subtropic deserts, as regards the character of chemical processes. This has been more than once pointed out by geographers and geochemists (2).

3. The combination of a low velocity of chemical processes with the absence of large quantities of the mobile phase of water, connected with the low pH and the ascending currents, gives rise to a number of geochemical and geological processes typical of Polar regions. The most important are:

1) Ascending currents produce both discolorations and crusts analogous to the sunburn of deserts. Black coatings and manganese films are characteristical of the latter (3), while the former are characteri-

zed by discolorations of soluble salts, frequently reported in glacial regions but very poorly studied chemically. To these refer the glacial stems as yet poorly studied, which arise at frosty nights with a comparatively low humidity ([4]) and present interesting minerals of geological importance, since they lead to a shifting of fine-grained earth and its division according to size.

2) The mechanical disintegration leaves behind the geochemical alterations of rocks and minerals, giving rise to a number of characteristical points in polar geochemistry. For instance: the mechanically accumulated sands in the Arctics and Antarctics usually correspond to the initial rocks both in composition and colour. Such are the remarkable olivine sands of the Antarctic, the green olivine and pyroxene sands of the Monche-Tundra at the Kola Peninsula. They preserve their ferro- and ferrisilicates unaltered and are thus clearly distinguished from the shore sands, e. g. from those of Baltic and Northern Seas, where silicates disintegrate and iron is carried away, or else from the sands of the Central Asia deserts, where iron is usually retained as red-coloured crusts (Kysyl-Kumy).

In this way a scheme may be traced of the colour of sands, from dark and green-coloured in the Arctics through the white sands of the middle latitudes to the reddish-yellow and black-red sands of desert regions.

The second characteristical phenomenon connected with the peculiarities of silicate hydrolysis is an almost total absence of transformation even of the finely disperse feldspar residue to clays and kaolins. Such is the remarkable preservation of feldspars of the volcano Erebus in the Antarctics (described by E. Shackleton in 1903); «sackfulls» of ideal samples of fresh crystals have been brought from there. From the practical viewpoint the absence of hydrolysis of feldspar particles leads to a great defect in the Polar region: the absence of high-grade clays, which are rarely encountered even at the Kola Peninsula.

3) The most important conclusion which may be drawn from the above statements as to the delay of chemical processes is certainly the absence of gossans of any importance and the highly reduced size of oxidation halos. In fact all those who have worked near the Polar regions are acquainted with the particular freshness of the samples, the absence of brownish-red crusts and films of hypergene alterations, especially sulphides. The zone of oxidation is confined only to millimeters or their fractions and accumulates usually only of the sulphide mineral itself, clearly localizing the brown spot only on the surface of the sulphide itself. From the practical point of view this phenomenon proved to be very useful in searching for sulphide ores in the Arctics. It should be noted as an example that the spot of a small pyrrhotite deposit at the Rischorr in the Khibina Tundras may, owing to its clearness, be seen with the naked eye at a distance of 15 km. The yellow spot on the nickel ores of Newduaivench in the Monche-Tundra was discovered by our party in 1930 through a field-glass from Mount Nittis.

4. The typical features of the geochemistry in the Polar regions find their expression in peculiar geochemical reactions and the presence of a number of minerals proper to the climatic conditions prevailing there. We shall list here the most typical and interesting mineral species:

1) Ice as a mineral is insufficiently studied. It presents a three-phase system of two components (H_2O+O_2) and has only in these last years enjoyed thorough mineralogical investigation under the leadership of Professor P. Niggli, in the Alps, at the Davos snow station; the first report was published in 1937.

2) Hydrohalite: $NaCl \cdot 2\,H_2O$. A remarkable lamellar mineral first described by Maak (1850) from the Kempendyaisk salines on the Vilui

river. Later on (1907) it was thoroughly studied by Dravert (5) during his exile under the tsarist government.

The formation of this mineral is being undoubtedly overlooked by polar investigators, and the needles and lamellae of hydrohalite and of its cryohydrate, the cryohalite which form during the freezing of salt water below 5° C, are evidently taken for ice crystals.

F. Vrangel has already written about this and about the roughness of polar ice. The scheme of its equilibrium as well as its development at winter-time in Baskunchak lake salt water has been well described by Nikolàiev (10).

3) S o d i u m c h l o r i d e. The phenomenon of salt water freezing presents an interesting geochemical process, described both in Polar Canada and in the north of the Kola Peninsula (6). Sodium chloride isolated in the course of this process (with other salts) forms a kind of discolorations like those of salts on glacial moraines (7). The isolation of salts at low temperatures might be used for industrial purposes at the north of the USSR, since the conditions prevailing in the White Sea allow chemical processes to be carried at temperatures below 0° C, at Kandalaksha for instance, within seven months. The chief part in evaporation is played by the wind.

4) S u l p h u r. The reaction of sulphur precipitation at low temperatures is very peculiar, which is shown by some interesting data [Ignatyevsky, 1832, and V. Vernadsky, 1914 (8)]. Sulphur is formed in result of the freezing of water and the isolation of hydrogen sulphide solved in it in regions rich in gypsum; owing to this, an isolation of sulphur takes place in waters of some localities in Northern province after the melting of snow; sometimes this gave rise to some home trade. If such a formation of sulphur cannot be regarded as a typical «arctic» reaction, it attracts nevertheless particular attention after the work on the Antarctic by E. Shackleton (1903) who when describing the volcano Erebus points to solfataras of yellow ice with finelly disperse particles of sulphur, as a remarkable mineral worth studying.

5) As to i r o n and m a n g a n e s e h y d r a t e s, certain formations are encountered in the near-polar latitudes, chiefly combined with a large quantity of water and hydropyrolusite in the first case and with limonite and esmeraldite in the second.

The formation of polyhydrates produce the clearly brownish-yellow tinges of the iron oxidation products and the black-dirty tinges of manganese.

6) A typical mineral of the northern regions is the a c c u m u l a t i o n o f o p a l as diatomaceous shells. This process is wide-spread in Polar Canada, at the Kola Peninsula, in Greenland, and probably in the northern regions of Siberia (chiefly in the part of Yakutia adjoining the Polar regions).

The deposits of diatomite, sometimes mixed with the sediments of sapropel, are of high practical value as a cementing substance in building, but so far they have been used successfully only in the Polar parts of Canada, where owing to the difference of levels the water is conveyed off the lakes rich in diatomite, whereupon the latter is excavated. Special attention should be turned to this question both at the Kola Peninsula and in the regions of Polar Siberia.

7) A typical mineral of the tundras adjoining the Polar regions is v i v i a n i t e, the bright blue phosphate of peat-bogs. Though it is known in very large quantities at the middle latitudes near Moscow and in White Russia too, its abundance and purity (without oxidation) is remarkable, e. g. in the Bolshaya Zemlya Tundra and in many logs of the Taimyr Peninsula, etc. This mineral may be recommended, on the one hand, as a cheap local blue paint, and on the other, as a fertilizer for field areas poor in phosphorus.

8) A peculiar but altogether unstudied compound is presented by the phosphates, forming out of huge quantities of g u a n o accumulated at the places frequented by sea-birds. This compound has not been studied geochemically in polar conditions though such a great quantity of accumulating phosphorus compounds cannot remain without influence on the substratum. If we cannot expect to find here such great accumulations of phosphorites, as those formed out of guano at the coral islands of the tropics, nevertheless the study of these from the viewpoint of the problem of phosphorus migration is of considerable interest. It should be noted that in 1845 an attempt was made to export guano from the Kolguief Island for the purpose of fertilization. The peculiarity of these processes has been noted in due course by A. N. Nordenscкiöld, a clever geographer and mineralogist.

9) But the most remarkable mineral of the northern seas is probably the «White-Sea corner-stones» (9), observed first by N. Scheglov in 1924 and later on repeatedly described by Decloizeaux, Sokolov, P. Eremeev, Dravert, and others. These minerals are hauled by the drag-nets of fishermen from the depths of the White Sea near the town of Archangel and are sometimes 12 cm long and 2.5 cm thick. They are moreover encountered in great quantities both at the mouths of many polar Siberian rivers and in some Tertiary and Quaternary rocks of Spitzbergen and Novaya Zemlya. The Mineralogical museum of the Academy of Sciences possesses a very rich collection of this mineral which remains misterious even at the present time. A detailed description was made as early as in 1882 by P. Eremeev, who determined the «corner-stones» as pseudomorphs of aragonite after celestine, though the author has noted a striking likeness of these with the crystals of the so-called pseudo-gay-lussite.

So far we have no definite data concerning the problem, but without any doubt Eremeev was mistaken. These are chiefly pseudomorphs of calcite after some mineral, most probably gay-lussite ($Na_2CO_3 . CaCO_3 . 5H_2O$). They are probably formed at the mouths of Polar rivers at the inflow to the ocean waters rich in sodium chloride, supplying an excess of calcium carbonate. The formation of gay-lussite in the slime of these mouths corresponds to the low temperature of the chemical processes and to the high content of carbon dioxide. This is confirmed by the formation of analogous products along with sodium carbonate and galite during the cold seasons in the lakes of the Mongolian deserts.

A further metamorphization of gay-lussite to pure calcium carbonate is very probable and corresponds to the higher stability of the latter compound.

The necessity of a further investigation of these remarkable products by our oceanographers and mineralogists should be emphasized.

5. From this short review it may be seen that both geochemistry and mineralogy of Polar regions are of highest scientific interest even with regard to special minerals, since it traces a peculiar complex of low temperature chemical processes. At the same time it should not be forgotten that aside from these formations accumulations of cosmic dust (cryoconite) are manifested in the areas adjoining the Polar regions; in other parts of the earth these accumulations become mixed with the earth's dust and are unavailable. So far cryoconite remains a misterious and insufficiently studied formation, but its significance in the general history of the earth cannot be denied.

The study of specific Polar geochemical reactions is at present highly important. Some work has been done lately in this respect by Scandinavian and Danish scientists (L. Koch, Högbom, O. Böggild, etc.).

Numerous data are supplied also by Canadian and North American scientists especially in connection with the investigation of Alaska and the economic study of mineral resources of Polar Canada (Ag, U, Ra, Co, Cu, etc.).

The highest importance, however, should be attached to this work in the Soviet Union, where the study of the geochemistry of Polar regions is already successfully started by Klenova and other scientists; the data obtained by the North Pole station will yield a material of the highest value for this study.

However, in the study of the Arctic it is not only and not mostly the peculiarity of the described specific minerals that is fascinating; we are interested chiefly in the remarkable mineral accumulations of the Arctic of the North Polar circle, where the richness of ancient shields is increased by the youngest tectonic and magmatic processes. The description of these is not within the scope of the present paper, but it must be borne in mind that the Arctic sector of our country is the chief source of P, Ni, Cu, Co, F, and probably of a number of rare metals, coal, salt and gases too. A detailed geochemical and mineralogical study of these regions is quite indispensable.

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MINERALOGY

ON SOME CURRENT PROBLEMS IN THE STUDY OF THE ICE OF THE ARCTIC REGIONS

By V. I. VERNADSKY, Member of the Academy

1. The scientific culture of a country is capable of rapid growth only provided conscious efforts are made towards its development; it does not come by itself; it is a common cause of all the scientifically thinking citizens of the country which have their will directed towards some definite scientific problems.

A scientific organization is always essentially a great united democratic organization of mankind, but its form differs from one country to another.

The profound scientific study of the Arctic which has been carried on during the recent years with ever growing intensity in our country, should attract particular attention and thought on the part of all those of us for whom scientific interests are precious.

In my present brief notice I wish to direct attention to three problems, the solution of which requires collective efforts.

2. It is easy to understand that a scientific study of the Arctic should be carried on simultaneously with a parallel study of the Antarctic. This has been always clearly realized in our country when the study of the Arctic regions of RSFSR was growing more extensive. At the epoch of Peter the Ist, who sent the Great Northern Expedition which lasted decades, an attempt was made to direct the expedition to Madagascar and further southward to the unknown at that time Antarctic. During the epoch of the second rise of the Arctic investigations in Russia, in the first third of the 19th century, Russian seamen and scientists (such as F. F. Bellingshausen, 1779—1852, who has as yet found no due acknowledgment) sailed round the world to the Antarctic waters; these journeys were of great importance. In this century, at the same time with the organization of the Polar Commission at the Academy of Sciences, the question was raised as to the renewal and organization of the study of Antarctic regions. Now this problem is included into the scientific plan of the Soviet Union as a well grounded practical task. It should be taken into consideration that the ice of the Antarctic is m i n e r a l o g i c a l l y n o t i d e n t i c a l with that of the Arctic, but so much important is their parallel study. My present communication is concerned with the Arctic ice only.

3. The first problem is to determine the m i n e r a l o g y o f w a t e r for the Arctic, in the first place to establish precisely all the mineral species of the Earth waters in all the forms of their occurrence—gaseous, liquid, mesomorphous and solid. Curiously enough, in mineralogy which is the

oldest of the geological sciences we see very little advanced the fundamental problem of the descriptive history of nature, viz. a precise and complete determination of «natural bodies», such being the minerals which are here the subjects of investigation. In the recent years I have made an attempt at doing this for Earth waters (1) and have obtained an unexpected result, namely, that the number of these minerals is very large, that the waters of the Earth are the largest group of minerals. In 1933 I succeeded in establishing for the Earth waters 485 species, referring to 129 families, classed in turn among 39 subkingdoms which are grouped in 19 kingdoms (2). A further study of these phenomena enables me to state that now (1938) 553 species of Earth waters may be distinguished, referring to 145 families, united in turn in 43 subkingdoms.

The work is as yet far from being completed and it is hardly probable that these numbers comprise one third or one half of all the Earth waters existing. Their total number is not less than one thousand; it may be much greater.

An exact description of individual species of Earth waters and their further study is the fundamental work to be done in the first place, it should be never relaxed in the mineralogy of waters. It confines the research to certain limits and determines the precision of work.

It helps to form an idea of the accuracy of our knowledge in this field. In this respect not everything is well in the study of mineralogy of our country.

The mining prospecting, extensively developed in our country, has furnished the scientific investigators with abundant new material. Yet we see that the number of the new minerals, scientifically established in our country, is far from that which could be expected from the abundance of data available on the object of mineralogy. I take it as evidence of how unsatisfactory the mineralogical study of the results of geological prospecting is. Undoubtedly it should tell upon the regularity and completeness of the practical deductions made.

The quality of observations made at the North Pole Station appears to me as one being above the average, for already from preliminary descriptions I see that they reveal new mineral species of Earth water. The mineralogy of the Arctic waters—ice in particular—should be established and compared with the mineralogy of the Antarctic waters.

4. Another problem is a biochemical one. It is connected with the biogenic history of silicium and aluminium.

One of the principal tasks of geochemistry is the study of these two elements—silicium and aluminium, since both of them together with oxygen determine the processes in which all the phenomenon of the Earth's crust are involved. Their oxygen compounds determine the medium of these processes. Their geochemistry is known only in general features.

In particular, for the Ocean they acquire still greater importance when we have to deal with the history of life in the Ocean—with biogeochemical phenomena. We seem to face here the most profound influence of life in the geology of the planet.

J. Murray has established, as a result of the Challenger Expedition, an immense process of this kind in the chemistry of the World Ocean. He has revealed the rôle played in it by diatomeae. Further investigations have only confirmed this phenomenon, foreseen by K. Ehrenberg a century ago. It is manifested in that millions square kilometers of silt sediments of the present-day Oceans are covered with a layer of remains of diatomeae, presumably tens of meters thick. This process in this form may be precisely traced back into the ages, without any conjectures, at least up to the Carboniferous, i. e. over 300—350 million years. Probably it continues much further back.

Murray showed that the siliceous diatomeae have the capacity of not only obtaining the necessary silicium from sea water (and owing to their rate of multiplication they absorb it so rapidly that a sea water lacking silicium may result), but also of obtaining it from the clayey, hard particles, dispersed in sea water and making it turbid. This capacity, lacking biological explanation, should be payed particular attention owing to the quite original chemical character of the «clayey particles». For Murray who considered them as acid aluminium salts of silicic acid, this seemed very simple and feasible, but in reality the structure of clays is quite different from that supposed by Murray, and such a reaction is not possible under usual conditions.

Clays are alumosilicic oxyacids possessing an extremely stable aluminosilicic complex—the k a o l i n n u c l e u s, consisting of atomic tetrahedra, in the center of which there are atoms of silicium or aluminium in a definite ratio (always two atoms of aluminium and two or more atoms of silicium), while at the corners of the tetrahedra there are atoms of oxygen. This kaolin complex is extremely stable, it may be destroyed only under the action of strong acids and has thermal properties playing a great rôle in the chemistry of our planet, since alumosilicates of this structure constitute the prevalent part of the Earth's crust by weight. This complex is endothermal, and when it is disintegrated heat is evolved (15.8 ± 2.5 calories per molecule). From this an idea can be made of how enormous should be the amount of heat evolved—and used by diatomeae—during such a disintegration of kaolin nuclei.

Therefore, in spite of his experiments, Murray's explanation seemed to require checking and further investigation. During my sejourn in Kiev, I organized experiments (1918) (together with A. Ogloblin and M. Bessmertnaia) at the Ukrainian Academy of Sciences and became convinced of the accuracy of Murrays's statements. In 1924, from report on this subject at the Paris Academy, it became known that Coupin at the same time with me made similar experiments and arrived at the same result(3). In the experiments carried out by me, Coupin and evidently in Murray's experiments too, a large quantity of bacteria was present. Owing to this fact the same experiments are actually carried on in our Biogeochemical Laboratory by E. A. Bojchenko and A. P. Vinogradov with a m e d i u m f r e e f r o m b a c t e r i a, and a similar result is obtained (4). Attempts are being made to throw light on the mechanism of the process.

Now it may be easily understood what a great importance a more detailed study of the process found by Murray to take place in the Ocean, has in determining out the rôle of life in the structure of the biosphere. Its connection with the character of the ice of the Arctic and the Antarctic is quite evident.

In this study it is convenient to evaluate t w o p h e n o m e n a to which particular attention should be attached.

First, the peculiar distribution of diatomaceous silts. They are observed in the near-polar regions of all the three Oceans—the Atlantic, Indian and Pacific. However, there is an anomaly. Viewing the map of silts (5) we clearly see that in the Pacific Ocean they are observed both in the Antarctic and in the Arctic. In both cases they are separated from the near-polar ice by terrigenous silts, produced by the melting of ice and glaciers and dating far back to the glacial phenomena of the post-Pliocene. In the northern part of the Indian Ocean, washing only Antarctic ice and separated from the Arctic by land, diatomaceous silts are absent.

But the same absence is observed for the Atlantic Ocean. The belt of diatomaceous silt in its south, distinctly pronounced in the Antarctic, is separated from the Antarctic ice by a large belt of terrigenous formations. It is absent in the northern part of the Atlantic Ocean. It is substituted by

globigerina ooze, which stretches across the whole of the Ocean to the northern boundary of the diatomaceous silt in its southern part. What is the cause of this phenomenon? Should it be sought for in the recent history of disappearance of the ice cap, left only in Greenland and on the islands surrounding the continents of America, Eurasia, playing no such part in the Arctic Ocean, adjacent to Eastern Asia, to the Pacific Ocean, to the Bering Strait? Or in the distribution of sea currents, disturbing the usual regime of the plankton, or else in peculiar conditions of life of the diatomeae of the northern part of the Atlantic Ocean? Is it possible that the ice cap of North-East Siberia had disappeared earlier, when Europe and America were still covered with it? Or will the study of the sediments of the Arctic Ocean—just in the region near the North Pole—reveal not terrigenous sediments but diatomaceous silt?

This is the problem which should be solved in the first place. It can hardly be done, however, unless study and quantitative evaluation be made of the «eating away» of the icebergs and ice-fields by diatomeae, which process seems to be extensive in the northern part of the Atlantic Ocean and in the ice of the Siberian coast. This phenomenon is connected with accumulations in ice and near it of diatomeae, finding there abundant food, intensively multiplying and evidently using «clayey particles», penetrating the ice, and reproducing the reaction noted by Murray.

It should be borne in mind that on the decomposition of kaolin nucleus heat should be evolved and that the «eating away» of ice by diatomeae may be the result of heat given off during the biochemical decomposition of clay, of its kaolin nucleus.

This phenomenon requires now a careful study and should be included in the plan of research. In the country, to my knowledge, only I. Palibin([6]) had been concerned with this problem.

5. I shall devote here a few words to a third problem of a cosmic nature, connected with Arctic ice. I have attempted, unfortunately with no success, to raise this question when discussing the program of the last International Polar Year and have written on this subject to O. J. Schmidt in connection with the work of the North Pole station.

What is cosmic dust—we do not know exactly. It is possible but not yet proved that it is connected with shooting stars, and it is highly probable that it essentially differs from meteorites ([7]).

One of the few methods of its study, and the most reliable one, is a study of the hard particles included in snow and ice of areas far removed from cultural life.

A systematic study of Arctic ice from this standpoint may reveal a terrestrial and cosmic phenomenon of such a scale and significance which now cannot be even suspected. This study should be organized and connected with an investigation of ice from the eternal snows of the Antarctic and from isolated high mountain summits and ridges of the Arctic.

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GEOCHEMISTRY

COLOURING OF POLAR SEA SEDIMENTS

By M. V. KLENOVA

(Communicated by V. I. Vernadsky, Member of the Academy, 30. III. 1938)

The colour of the sea bottom sediments is one of their most characteristical features. Naturally enough the indications as to the colour of the ground—«grey, white, green», etc.—appeared already on the first sea-maps along with the designations: «sand, mud», etc.

The colour characteristics have been introduced also into the classical classification, made by Murray after the oceanographic investigations of Challenger Expedition; such designations as «blue mud», «green sand», «red clay» are generally used. Further investigations have very soon shown that these designations of colour are arbitrary: pure colours are practically very rarely observed in the colouring of the sea bottom sediments; there is always a whole scale of intermediate colours. This is particularly striming in the investigations of Polar sea sediments, and the first investigators of these sediments, as e. g. Schmelk (1), have already used such expressions as greenish-grey, greyish-green, yellowish-brown, grey-black, etc. mud.

The same investigator has first attached attention to the difference in colouring of various layers of sediments in the Greenland and Norwegian Seas, where (as it has been shown later on also for other parts of Polar seas) the upper layer is brown, and the lower—of different tinges of grey. Schmelk as well as later investigators (Böggild, Samoiloff and Gorshkova (2) and others) put down this difference to the varying quantity of ferric and ferrous oxide and to the chemical composition of the sediment in general (3). The very first investigators, Schmelk, Thoulet, Böggild, tried to find out which are the physico-geographical factors accounting for the colour of the sediments developed.

The tinges of sediments are unstable and may easily be identified only in a fresh state, after the sample has been just taken out of the bottom. When drying in the air and light, the colouring changes and some tinges, which have been very characteristical in a fresh wet state, fade altogether; they should be studied, therefore, immediately after taking out the samples; for this reason a specialist—marine geologist—should always participate in every oceanographic expedition (4). Owing to this lack of stability certain standards should be used in describing the colours, since every one of the investigators as concerned with a description of the manifold tinges makes use of different words and expressions frequently imparting them his individual impression.

This question was encountered as soon as the investigations of the geology of the sea in the Institute of Oceanography were started on a large scale. At the same time, in 1930, the author arranged a collection of sediments of the northern seas, most typical with regard to colour; these samples made up a definite scale of tinges embracing all the principal colours, as black, green (not pure), bluish-grey, grey, pinkish-grey, greenish-grey, yellow-grey, brown and dark-brown. Since it has been impossible to preserve all the typical colours of fresh ground in the natural samples, the scale has been made of a mixture of oil-colours ([6]), which were laid on small planks and used later on by the author and her collaborators in the studies of marine sediments as standard ([5], [6]).

Other investigators also met the necessity of fixing the changeable tinges of ground colours. Thus, O. Pratje ([7]) used Ostwald's scale in studying the sediments of the North Sea, while American investigators use the scale of sedimentary rock colours ([8]).

Having introduced into practice the method of direct determination of the ratio of ferrous oxide to ferric oxide, i. e. the redox coefficient ([5]), we succeeded in establishing not only its value for sediments of different colours, but also its dependence on the gas regimen and on the presence of organic matter.

When studying the submarine weathering, author was successful to establish the fact that the development of brown colouring in the northern seas is connected with certain physico-geographical conditions ([9]).

In the light of the present knowledge of the structure of matter, all the regularities in the distribution of the northern sea sediments may find their explanation in energetics.

It is familiar that with the increase of the number of absorbed rays in the spectrum we observe a gradual extinction of rays directed from greater to smaller wave lengths, so that the spectrum has its colours successively fading in the direction from grey to greenish-yellow, yellow (not pure), orange, red with a brownish tinge, brownish-red, reddish-brown, to black at a complete absorption of light, and finally, to metallic steel-blue and metallic golden. This light absorption range embraces all the colours of opaque mineral bodies, including the sediments of the sea bottom with their diversity of shades nearly escaping observation, as dull greenish-grey, brown, etc.

This colouring of mineral bodies depends upon the presence of atoms of different elements in a state of polarization, i. e. upon the asymmetry of crystalline lattices. According to an excellent expression of A. E. Fersman ([10]), the more confusion there is in the electrical economy of the crystal, the higher is the light absorption, the deeper the colouring. From this viewpoint the laws governing the colour of the sediment and the physico-geographical conditions of its sedimentation previously observed receive a more profound explanation and a deeper geochemical significance. This is particularly conspicuous in the Barentz Sea, and in general in Polar seas, but the same regularities may doubtless be traced in other recent and fossil sediments too.

In Polar seas we may above all observe the dead grey colour of rapidly depositing sediments near active glaciers. This is a stable and monotonous colouring. It is retained at the erosion of the Quaternary clay of Murman ([11]) and at the submarine ridges under a thin layer of recent sediments.

Poor is the reserve of energy stored up in these deposits; the quantity of buried organic matter is small.

In the deep portions of the fjords of Spitzbergen and Novaya Zemlya and at the submarine slopes the grey colour of the sediment acquires greenish-grey and yellowish-grey shades, depending on the good ventilation of the

bottom water and the extensive development of organic life. Intense interaction processes between two terrestrial envelopes along the boundary of two media produce a red-brown oxidized coating. Correspondingly in the zone of «geochemical inconsistency» ([12]) grows the polarization of atoms, the «confusion» in their electrical economy. It may be clearly seen in the sea that the brown coating of oxides is associated with the boundary between two media—solid and liquid. In the desert the brown and black coatings of sunburn also accumulate in the boundary zone.

The brownish-red colour of the oxidized film on greenish-grey sediments is unstable. The store of solar energy supplied by the North-Cape current creates conditions for an opulent development of organic life. This solar energy, set free in the course of disintegration of organic matter, rapidly arranges the electrical economy of the atoms—iron is reduced. Under a thin brownish-red film the sediment retains a greenish-grey colour, but if the quantity of organic matter is considerable and the sediment is dense, so that the access of oxygen to the lower layers is obstructed, the latter are covered with a black coating of ferrous sulphide.

In deeper and calmer parts of the basin a poor ventilation of the bottom water layer under cold polar water causes carbon dioxide to accumulate in the presence of a sufficient amount of oxygen. For this reason an impoverishment of the bottom fauna takes place, while the brown layer obtains its maximum development. But here too it is not perfectly safe from some influence causing its change: with the accumulation of the sediment and its withdrawal from the boundary zone it is gradually reduced and turns grey, but not mouse-grey, as a sediment of glacier milk, and mostly not greenish-grey, as the sediments in Atlantic waters, but slightly bluish or pinkish-grey, since phosphorus and manganese are concentrated in the brownish-red film together with iron. It is known that the brown sediments of Polar seas ([13]) in spite of the poor bottom fauna contain organic matter almost in the same quantity as greenish-grey sediments, and only occasionally this quantity is somewhat less. The source of organic matter is the plankton, i. e. here again the solar energy concentrated in green cells of algae arranges the electrical economy of the atoms.

The brownish-red iron oxides evolve heat while forming and their energy is turned to account by iron-bacteria; the activity of the latter leads to the formation of concretions, to the weathering of stones at the sea bottom, etc. The bacterial life brings about the formation of stable dark-brown and black iron and manganese oxidized compounds which are preserved also in the fossil state. Stable compounds of this type are accumulated in deep-water clay and that accounts for the latter, though it is usually called red, not being red at all but chocolate coloured, and in this colour it approaches to certain sediments of the Kara Sea with 1.5% Mn.

As may be judged by the preliminary data obtained by the North Pole station, the grounds collected in the Polar basin by P. P. Shirshov show the presence of a large number of stations of brown mud underlain by grey mud. The presence of grey mud, though only in the lower layer of the core, shows that the quantity of organic matter is quite sufficient to create a reductive medium and to convert the most part of mobile soluble iron and manganese compounds into protoxides *. This is quite in harmony with the rich plankton life observed by the investigators who passed the winter in the Polar basin.

* Whether the lower layer is the result of a more ancient sedimentation, or whether the latter was proceeding under conditions different to those prevailing nowadays, will be shown by more detailed studies.

At most stations the brown layer was well developed, comparatively thick, attaining according to P. P. Shirshov and I. D. Papanin's report one half of the column, i. e. about 10 cm at the depth of 4395 m, station at 88°09′ N. lat. and 3°00′ W. long.

According to this it may be stated that: 1) in this region the oxygen reaches the very bottom; 2) the water at the bottom, moving slowly, is saturated with carbon dioxide; 3) the bottom life is comparatively poor; 4) the chief source of organic matter in the ground is the plankton. The quantity of manganese and phosphorus may be assumed as somewhat higher compared to the sediments of more southern regions. In the Polar basin and its marginal seas the sesquioxides are deposited which are washed out by Siberian rivers from the grounds in the course of podzol soil formation.

In conclusion we cannot but express the wish that the most interesting material collected by the North Pole station should be studied most thoroughly and by such methods which would make possible an immediate comparison with the data obtained in other Polar seas of the USSR.

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GEOCHEMISTRY

ON THE CONCENTRATION OF CALCIUM CARBONATE IN THE WATERS OF THE POLAR BASIN

By N. I. TCHIGIRIN

(Communicated by S. A. Zernov, Member of the Academy, 28. III. 1938)

Unquestionably one of the most important results of the works of the Papanin group is the discovery of a warm water layer of Atlantic origin in the central parts of the North Polar basin.

Up to not long ago the data at hand on the circulation of Atlantic waters in the deep section of the Polar basin led to the conclusion that owing to the deflecting action of the earth's rotation the Atlantic waters, which flow into the Polar basin from the Greenland Sea, round Spitzbergen and follow further eastward, keeping close to the continental slope of the Polar basin and penetrating through deep straits into more southerly seas. Up to the investigations made on the drifting ice-floe there were no grounds on which to build a hypothesis as to how far north the Atlantic water stream penetrates.

The discovery of Atlantic waters near the North Pole in the centre of the Polar basin by the Papanin group was therefore quite unexpected and leads to the conclusion that the Atlantic water stream flows through the greater part of the Polar basin. This imparts a broader and more universal nature to all problems of Arctic oceanography, dealing with the study of the rôle and significance of Atlantic waters in the Polar basin.

Besides having a higher temperature and greater salinity, the Atlantic water of the intermediate layer differs from the waters of the Polar basin in its chemical composition. These distinctions are most obvious when certain values characterizing the chemical composition of Atlantic waters are compared with those of the water in the Polar basin.

A comparison of the content of calcium carbonate in waters of various origin is of special interest in this connection inasmuch as various physico-chemical conditions, the intensity and to some extent the direction of biological processes make it possible to expect a more or less pronounced difference in the distribution of calcium carbonate.

The material on the chemistry of the waters in the Polar basin collected by the High-Latitude «Sadko» Expedition in 1935 threw some light on this problem. After reaching a latitude of 82°41' the expedition succeeded in entering the deeper parts of the Polar basin and investigating some samples of water from layers of various origin.

The chemical determinations included among others a series for determining the magnitude of the alkali reserve and the concentration of hydrogen

ions. From the results of these determinations the relative contents of calcium carbonate expressed in grams of $CaCO_3$ to 1000 g of salts and the degree of saturation of the water with calcium carbonate were calculated.

In the part of Polar basin, adjoining the Kara Sea, which was investigated by the «Sadko» expedition, three types of water may be differentiated according to their chemical characteristics. In the northern most deep-water station of the «Sadko» expedition the top layer, from the surface down to about 100 m, consists of water with the greatest content of calcium carbonate, viz. 3.42—3.60 g to 1 kg of salts. This layer is to a highest degree exposed to the influence of ice and also of continental waters which flow from the south out of the Kara Sea. Below this there is a layer of warm Atlantic water; great masses of water with a positive temperature are situated approximately between 110 and 950 m. This layer has a low content of calcium carbonate, viz. 3.37—3.39 g to 1 kg of salts. Beneath the layer of Atlantic water down to the very bottom, the water has a negative temperature and a higher content of calcium carbonate, viz. 3.39—3.49 g to 1 kg of salts.

Judging by these ranges of calcium carbonate content in water from various layers of the Polar basin, we draw the conclusion that the water of the upper layers as well as abyssal water are quite rich in calcium carbonate, in comparison with the water of the warm Atlantic layer. These differences are even more conspicuous if the above values of calcium carbonate content are compared with the values obtained by the «Sadko» expedition for Atlantic water currents in the Greenland Sea. The Atlantic water that flows into the Greenland Sea without changing its composition contains 3.33—3.35 g calcium carbonate to 1 kg of salts. Comparing this with the above figures, we see that the concentration of calcium carbonate in the warm layer water is 1 per cent greater than in the water of the Atlantic Ocean, while in Arctic waters this increase may exceed 5 per cent.

The solubility of calcium carbonate in sea-water depends upon the content of free carbonic acid, the temperature of the water and the hydrostatic pressure. Taking these facts into account we calculated the degree of calcium carbonate saturation of the waters in the region investigated by the «Sadko» expedition.

The results obtained have been found quite characteristic—the Atlantic water layer is supersaturated with calcium carbonate, while the upper as well as the abyssal layers of Arctic water are not saturated with it. In the Atlantic waters in the Polar basin the saturation with calcium carbonate is 101—103 per cent and for the Arctic waters it is not over 98 per cent. Supersaturation with calcium carbonate is a characteristic peculiarity of Atlantic waters, and in streams of the Atlantic current in the Greenland Sea it reaches even greater values: 105—115 per cent.

Thus, while flowing from the Greenland Sea to the North Land the Atlantic water remains almost unchanged in relation both to its calcium carbonate content and the degree of saturation with the latter. This resistivity of Atlantic waters to metamorphosis is evidently retained for a long period, until they have been completely cooled, and intermix with Arctic waters. The wide distribution of non-metamorphized Atlantic waters in the Polar basin, proved by investigations of the Papanin group, confirms this conclusion.

The non-saturation of abyssal and bottom waters with calcium carbonate is of great importance. If the waters are not saturated with calcium carbonate, then the solubility of suspensions containing calcium carbonate, which are precipitated out of the upper layers, rises and the calcium carbonate of sea-bottom deposits dissolves as well.

On the other hand, a low degree of saturation of water with calcium carbonate makes it difficult for organisms to extract calcium, since calcium carbonate is extracted intensively only in the waters which are supersaturated with the latter.

The low intensity of the extraction of calcium carbonate from water and the conditions favouring the dissolution of calcium suspensions and sea-bottom deposits result in a decrease in the content of calcium carbonate in the bottom soils of the Arctic and the accumulation of an excess of it in the water.

Since the upper layers of the Polar basin are not saturated with calcium carbonate, we find here the same phenomena as were mentioned for the abyssal layers, i. e. the solution of calcium suspensions and the difficulty for organisms to extract calcium. Besides that, the formation and the melting of ice has a great influence over the content of calcium carbonate in the upper layers.

During the formation of ice more calcium carbonate freezes into it than chlorides of sea-water. The relative increase of the calcium carbonate content in ice greatly rises with ageing of the latter. Thus, in ice many years old cases have been reported where the relative content of calcium carbonate had risen more than a thousand times in comparison with sea-water.

Accordingly, when aged ice melts, the relative content of calcium carbonate in the water of the upper layers of the sea rises considerably.

Summarizing all this, we arrive at the conclusion that in the Polar basin both surface and abyssal waters contain excess quantities (in comparison with Atlantic water) of calcium carbonate and yet are not saturated with it. The supersaturated waters of the warm Atlantic layer which metamorphize very slowly are an exception.

The excess of calcium carbonate accumulated by the waters of the Polar basin is to some extent carried away by surface and abyssal currents and especially by ice-floes into the Atlantic ocean, where it compensates the deficiency of calcium carbonate in the low latitudes. Thus, the interchange of waters between ocean regions of high and low latitudes, in which the processes of accumulation and extraction of calcium carbonate are of various nature, tends to equalize the concentration of calcium carbonate in the oceanic waters of the earth's crust.

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BIOCHEMISTRY

OXIDATION-REDUCTION POTENTIAL AND THE pH OF SEDIMENTS OF THE BARENTZ AND KARA SEAS

By S. W. BRUJEVICZ

(Communicated by A. N. Bach, Member of the Academy, 22. III. 1938)

The distribution and origin of the oxidized brown sediments with a considerable manganese and iron content and high oxidizing power are of great interest from the geological and oceanographic standpoint. These sediments known in the Polar seas of the European-Asiatic sector and Greenland Sea ([2], [5]) comprise, as it has become known after the studies of the drifting North Pole station ([6]), probably the greater part of the abyssal depths of the Polar basin. In the region of the European and near-European Arctic, which we are directly interested in, the brown sediments are spread in the White Sea, the northern part of the Barentz Sea and nearly the whole of the Kara Sea. Our investigations, carried out in the 40th expedition on the «Perseus» in September—October 1932, embraced the region around Spitzbergen island, the northern part of the Barentz Sea and the Kara Sea. With the exception of Cooper's paper on the determination of E_h in sea water ([7]) there is only one published article of Zoßell ([8]) concerning the determination of redox potential in sea bottom deposits.

P r o c e d u r e. The redox potential was determined with the aid ot smooth platinum electrodes. The rate of establishment of the potential under favourable conditions is up to 2 hours. The redox potential (E_h) is referred to the normal hydrogen electrod. The pH of marine sediments was, as a rule, determined after the hydro-quinhydrone method. The method is suitable for all sediments, except those containing manganese peroxide. The value of pH is given without reducing it to the temperature in situ ([1]).

F a c t o r s C o n t r o l l i n g t h e pH o f B r o w n S e d i m e n t s. The brown sediments are characterized by the presence of higher manganese oxides and of ferric hydroxide. The E_h of the mixture of ferric hydroxide and ferrous hydroxide, calculated after the formula of Kriukov and Avseevich ([4]), assuming that the product of solubility for $Fe(OH)_2$ is equal to $3 \cdot 10^{-20}$ (average from the data by Britton and Sweney), is equal to 47 millivolts. Practically, I could obtain no paste of $Fe(OH)_2 + Fe(OH)_3$ with an redox potential above +40 millivolts. The potential of the medium containing an excess of Mn_2O_3 with pH=8, calculated after Britton, is equal to 497 millivolts. The potential of the paste of manganese hydroxide, oxidized by air to a black colour, which I have determined, was found equal to 490 millivolts with pH=7.81. Thus, it is only to the presence of higher manganese oxides that the high E_h of the brown sediments is due.

Results of Expeditional Observations. The distribution of the sediments according to their colour presents a demonstrative picture. Spitzbergen is surrounded by yellowish-grey sandy muds without any brown film. East of Spitzbergen, in the whole of the northern part of the Barentz Sea (north of 77°) and throughout the Kara Sea, there is a film of very thin brown muds, underlain by greenish and bluish-grey muds ([3]). The grey muds surrounding Spitzbergen are characterized by a relatively low redox potential, on the average about +105 millivolts.

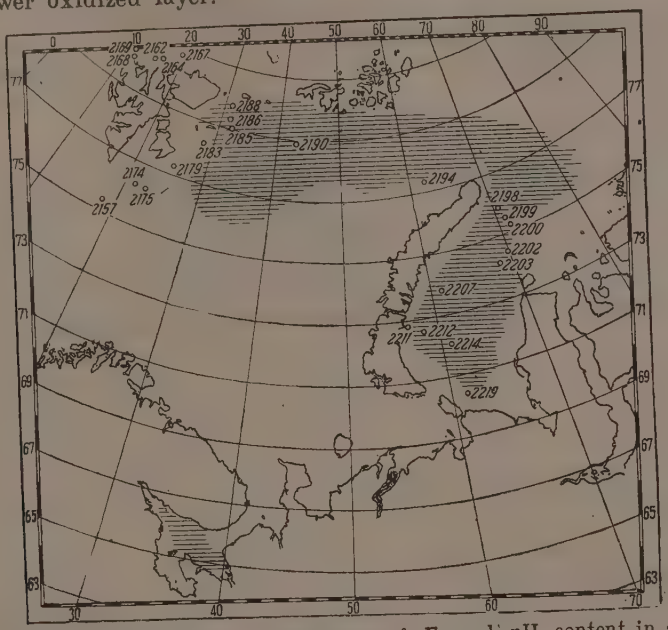
The brown sediments of the Barentz Sea with a considerable manganese peroxide content have a E_h of about 265 millivolts; the same brown sediments of the Kara Sea, on the average about 270 millivolts. Thus, the brown sediments of the Barentz and Kara Seas are practically identical as to their redox potential. As to the underlying grey grounds of various shades, the sediments of the Barentz Sea have a considerably lower potential (on the average 153 millivolts) as compared to the Kara Sea (on the average 224 millivolts). The latter, in spite of their bluish-grey colour, have a very high redox potential. The two groups of bluish-grey underlying muds of the Barentz and Kara Seas have a considerably higher redox potential than the yellowish-grey muds surrounding Spitzbergen (on the average —105 millivolts).

Particular attention should be given to the samples from stations 2186, 2194 and 2207, the analysis of which showed to a greater or lesser degree a mixture of brown and underlying grey mud owing to the intermediate layer being touched. In these samples, besides lower potentials (E_h: 126, 132 and 204 millivolts), a strong decrease of the reaction is noted (pH: 7.36, 7.46 and 6.76). In order to explain this phenomenon we must somewhat dwell on a comparison of the chemical composition of the brown and the underlying grey muds. Analyses made by Gorshkova ([2]) for the two sediments from the Barentz and the White Seas show that with regard to the silicate composition the two layers are practically identical, which clearly indicates that here there is no replacement of some deposits by others, but only an intensive process of diagenesis. The principal distinctions are restricted to a sharp increase of the content of ferric oxide in the upper brown mud and an enrichment in organic matter as compared to the lower layer.

The dynamics of the transition of brown mud into the grey one may be presented, in author's opinion, as follows: the primary substance reaching the bottom is brown mud or one approaching to it. Owing to the soft consistency of the mud and its being easily washed by water, which has a sufficient content of oxygen dissolved, no reduction of the higher manganese oxides by the organic substance of the brown mud, which seems to be a very stable one, takes place. As the mud becomes denser downwards and its washing with oxygen containing water becomes more difficult, begins the reduction by the organic matter first of the higher manganese oxides, and then of iron, which leads to the accumulation of carbon dioxide in the transitional layer. The bicarbonates of manganese and iron diffuse towards the more soft mud, i. e. to the region of brown mud, where they are reoxidized by dissolved oxygen. Since the solubility of manganous carbonate and hydroxide is considerably greater than that for iron, manganese passes almost completely to the upper layer, while a considerable part of iron remains in the lower layer. Thus, together with the growth of the film of brown silt, its qualitative change takes place too.

Insofar the accumulation of the sediment proceeds downwards towards an increase of the thickness of the upper layer, it is evident that the reduction of the oxidized layer at its lower boundary is the only possible way of diagenesis of the brown silt under conditions of an all-year presence of well aerated over-bottom water.

The boundary between the upper oxidized and lower reduced layers is an intensively working laboratory, where under conditions of a sharp decrease in the free dissolved oxygen takes place a reduction of the higher manganese oxides and ferric oxide at the expense of a simultaneously proceeding oxidation of the organic substances of the ground. This picture is in good agreement also with the distribution of the organic matter along the vertical, its content being high in the upper oxidized layer and low in the lower oxidized layer.



Map of the stations where determination of E_h und pH content in soils was made. The region of distribution of brown sediments (after M. V. Klenova) is hatched.

The origin of the oxidized sediments in the northern part of the Barentz Sea and the Polar basin seems to be connected with an accumulation of iron and manganese oxides, which owe their formation to the chemical weathering of the mineral material brought by ice—icebergs and off shore ice. The essential conditions here are also the rich oxygen resources of the sea and the small amount of dead organic remains falling to the bottom. The western and southern parts of the Barentz Sea, open to the waters of the Atlantic with their exceedingly low iron content (3—5 mg Fe/m³), are nearly free from the ice cover and are characterized by a complete absence of brown muds. A marked part is probably played here also by the considerable production of the plankton in this region, free from ice and more accessible to photosynthesis.

Reaction. The pH of the surface layer of the grey grounds northward of Spitzbergen and in the northern part of the Barentz Sea (stations 2174, 2175, 2179) varies within the range of 7.60 to 8.08, on the average 7.87. The average value of pH of the near-bottom waters is 8.10, the salinity being 34.5 to 35‰ and the temperature being zero to +3°. The pH of the lower layer in the Barentz Sea is 8.14 to 8.20, 8.29. The true value of pH of brown sediments could not be determined by the hydro-quinhydrone

method. The pH of the surface layer of the mud, as it had to be expected, is everywhere more acid than that of the near-bottom water. As to the relation between the pH of the upper layer of the mud and that of the lower layer, although the data available in this connection are very scarce, still we may conclude from the low content of organic matter and the extinction of oxidation processes in the lower layer that the value of pH in the latter is higher.

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HYDROBIOLOGY

BIOLOGICAL SEASONS OF THE ARCTIC SEA

By B. G. BOGOROV

(Communicated by I. I. Schmalhausen, Member of the Academy, 27. III. 1938)

In 1934, during the cruise of the «Litke» from Vladivostok to Murmansk, quantitative collections of plankton were made by the author in all the Arctic seas lying on the Northern Sea Route. The ice conditions in different Arctic seas and their separate regions greatly differed (see V. J. Vise). It was therefore possible to obtain plankton from sea regions which have been freed from ice at different dates.

In the regions still under solid winter ice very little phyto- and zooplankton was observed. Adult animals, eggs and spores of algae were chiefly found there. Such is the winter plankton.

At the ice edge and the water of large breaches in ice, we observed exuberant quantities of phytoplankton, the so-called «flowering» of the sea. Eggs, nauplii and the young of various animals were found to abound. Such is the spring plankton.

On expanses of clear water, «long ago» freed from ice, the total amount of plankton decreases considerably, while the part played by zooplankton, on the contrary, increases. As a rule, the latter was present in older age stages. Such is the summer plankton.

No species characteristic of regions with definite ice situation were discovered among zooplankton. The qualitative character of zooplankton was confined to changes of age categories depending upon the biological season of the plankton at a given point of the sea.

Let us quote two examples (Table 1, number for 1 cm^3).

Summing up the whole quantitative material of the «Litke» expedition, we obtained the following seasonal variations of the amount of plankton (Table 2).

When examining the distribution of phytoplankton and zooplankton in different Arctic seas and their regions, we observed in all cases that when the relative amount of phytoplankton was great, the relative amount of zooplankton was small, and vice versa. This is due to the fact that different regions of the Arctic seas are freed from ice at different dates; thus, at a definite moment in various regions, different biological seasons or their stages may be observed. It tells, moreover, on the quantitative correlation of phytoplankton and zooplankton, particularly since phytoplankton serves as food for zooplankton, eitheir directly or through detritus and bacteria after their dying off.

Table 1

Chukotka Sea

№ of samples	№ 32	№ 31	№ 30
Iciness (ice conditions)	Fast ice	Ice edge*	Clear water
Biological seasons	Winter	Spring	Summer
Pseudocalanus elongatus I stage	2	180	10
II »	11	110	20
III »	7	20	10
IV »	4	30	20
V »	7	10	10
VI »	17	10	—
Ova *Copepoda*	1260	2300	630
Nauplii *Copepoda*	300	3200	370

Kara Sea

№ of samples	№ 164—173	№ 193—195	№ of samples	№ 164—173	№ 193—195
Iciness ice conditions	Ice edge*	Clear water	Iciness ice conditions	Ice edge*	Clear water
Biological seasons	Spring	Summer	Biological seasons	Spring	Summer
Calanus finmarchicus			*Pseudocalanus elongatus*		
I stage	24	10	IV stage	10	200
II »	33	13	V »	4	—
III »	8	87	VI »	0.3	—
IV »	1	15	Ova *Copepoda*	42 000	164
V »	1	—	Nauplii *Copepoda*	3 400	11 500
Pseudocalanus elongatus			Larvae *Lammeli branchiata*	—	800
I stage	170	290	» *Gastropoda*	3	250
II »	50	420	» *Polychaeta*	—	204
III »	100	85			

Table 2

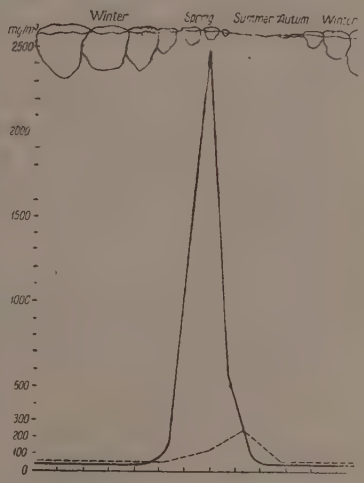
Season	Average titre (mg/m³)	
	of phytoplankton	of zooplankton
Biological winter	41	52
Biological spring	2470	122
Biological summer	560	230

* Water breach in ice-field.

Thus, examining the seasonal changes of the quantity of phytoplankton and zooplankton we arrive at the conclusion that the ratio of phytoplankton to zooplankton expressed in commensurable values (for instance, in weight) is a value characterizing the seasonal stage of plankton development in a given sea, region, locality, etc.

This ratio is the index of the seasonal stage of plankton. This «seasonal index» is found by dividing the amount of phytoplankton (in weight) by the amount of zooplankton (in weight).

Throughout a region recently freed from solid ice (on the edge, or in unfrozen patches of water) the «seasonal index» was very high (30—50), up to 120. Thus, at the culmination of spring «flowering» the amount of phytoplankton exceeded that of zooplankton by 120 times. During the biological summer, the index varies from 1 to 5—6, while during the biological winter, owing to quantitative prevalence of zooplankton over phytoplankton, it usually drops as low as 0.1—1.



Biological seasons of plankton in the Arctic sea. Yearly course of quantitative variation of phytoplankton (straight line) and of zooplankton (broken line). Above are shown the ice conditions (fast ice, open spaces, ice edges, clear water, new ice).

Seasonal changes in the life of Arctic Sea plankton proceed in the following way (Fig. 1). During the long winter, when darkness and ice dominate over the sea and prevent penetration of light into water, the development of phytoplankton is impossible. On the other hand, by that time there occurs an extreme enrichment of water with nutritive salts at the expense of the decaying of plankton and nutritive substances raised from the bottom by vertical circulations, as well as owing to the nutritive salts brought by the rivers, and, especially, to their being not consumed by phytoplankton. At that time, the total amount of plankton uses to be very small, the amount of zooplankton prevailing over phytoplankton. As soon as owing to spring shifts of ice and to melting the sea surface is exposed to the sun shine, an intensive development of algae sets in. Consuming the enormous supplies of nutritive salts accumulated during the winter, the phytoplankton reaches in a very short time a mass development, «flowering». Practically such regions are the edge of ice, the recently opened spaces, and the water breaches in the fast ice. At that period, the quantity of phytoplankton is tenfold that of zooplankton.

The huge masses of plankton rapidly consume the supply of nutritive salts. The decrease of the amount of nutritive salts is followed by a corresponding decrease of phytoplankton which dies off and develops at a slower rate. This decrease of phytoplankton is also influenced by an intensive development of zooplankton, consuming the phytoplankton. Thus, a maximum of zooplankton is established. By this time, large spaces of water become freed of ice.

After this, with the formation of new ice, the amount of plankton sharply decreases.

From the succession of biological seasons described for the Arctic sea and from the figure it becomes evident that in the Arctic seas, from the Kara Sea to the Chukotka Sea, there exists but one maximum of phytoplankton (which corresponds to the biological spring) and of zooplankton (during the biological summer). In other seas there exist usually two maxima of phytoplankton and of zooplankton. We may, consequently, call our Arctic seas m o n o c y c l i c in contrast to the others, which may be named b i c y c l i c seas.

This is accounted for by the v e r y s h o r t p e r i o d o f p e n e t r a t i o n i n t o w a t e r o f l i g h t stopped by ice, and therefore, by very short period of vegetation of the phytoplankton.

In these Arctic seas which abound in ice hydrological changes occurring during the year are relatively insignificant. Only the plankton suffers particularly sharp changes. Biological seasons may, therefore, be used to establish o c e a n o l o g i c a l p h e n o l o g y, a special branch of sea science, due to which it will be possible to judge of the seasonal state of the Arctic sea by the degree of plankton development.

As a matter of course, the connection between biological seasons in plankton and ice conditions may be used for local ice prognoses (indicators), the practical importance of which is selfevident. The experiment carried out by the author during the expedition on «Litke», in 1934, and by P. P. Shirshov on «Krassin», in 1935, who tried to base their ice prognoses on biological seasons, has been fully justified in practice.

In his highly interesting and important work Shirshov has established both seasonal shifts of phytoplankton, and «winter», «spring», and «summer» forms. Of particular importance is the determination by Shirshov, in 1935, during the expedition of the «Krassin», of the duration of separate stages of phytoplankton development, since they have a great importance in local ice prognoses based on plankton.

Further progress of the study of biological seasons, and of the ice prognoses based upon them, required a year-round material. Due to Shirshov's work at the drifting station «North Pole» which is of historical importance, it will now be possible to find out the changes of plankton during the chief periods of the year. The special, exceptional interest of the works carried out by Shirshov in the center of the Arctic basin is quite obvious.

Preliminary summaries and observations communicated by Shirshov in the daily papers tell about the discovery of biological seasons also in the severe conditions of Central Arctic. Shirshov, therefore, quite rightly considers that Nansen was wrong when he mentioned the exceeding poverty of life in the Arctic basin. This is characteristic for the «winter» state only, whereas during the biological «spring», as noted by Shirshov, there develops a tremendous amount of planktonic algae and of diverse animals.

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HYDROBIOLOGY

BIOLOGICAL ANALYSIS OF ICE-FLOES

By P. I. USACHEV

(Communicated by S. A. Zernov, Member of the Academy, 28. III. 1938)

When Nordenskiöld made his expedition in 1875—76 in the steamship «Proven», it was ascertained by the botanist Kjelman, for the first time in Arctic explorations, that drifting ice-floes in the seas carry a flora of diatomaceous algae. Nansen attached much importance to this fact during his expedition in the «Fram». Nansen made interesting observations on the accumulation of fauna and flora on the surface of ice-floes and on their lateral walls submerged in the sea water, and he was the first to point out the part such accumulations play in the melting of ice. The latter circumstance received explicit interpretation (1) in an article by Palibin «Microorganisms as Destroyers of Polar Ice». While working up the collections of Nansen and Blessing, Gran (2) summarized all the data collected by earlier botanists on diatomaceous algae of the Arctic region (Cleve, Grunov and others), and composed the first monograph on the ice-flora. Judging by the presence of certain diatoms in Nansen's collections and also from the assumption made by his predecessors, Gran distinguished two groups of ice-floes, different as to their origin, viz., «drifting pack-ice» of the Arctic Sea (drifting Arctic pack) and «ice of apparently local origin». Furthermore, Gran pointed to a great resemblance of the specific composition of diatoms from the polar ice near the Cap Vankarem with those collected by Nansen between 78°19′—81°30′ N. and 125°00′—127°30′ E., and finally, those from the polar pack-ice in the Greenland Sea. He considers this as an evidence of a general drift of ice-floes from the Far-Eastern Arctic regions towards the Atlantic Ocean. This fact once more proves the importance of such studies.

During the cruise of the ice-breaker «Yermak» through the northern part of the Barentz Sea in summer 1901, Palibin (3) was observing ice-floes and came to the conclusion that on their upper surface living diatoms are not to be found. This statement seems to be in no contradiction to the data of Gran based on Nansen's collections, since of the total of 53 forms of diatoms found on the surface of ice-floes (in depressions on ice, at the bottom of pools formed by melting ice and not connected with the sea) only two species were found to be alive. However, Gran himself maintains that diatoms had been living and multiplying on ice-floes. Palibin has furnished no detailed lists of diatomaceae or rather of their remnants, discovered by him on the surface of ice-floes; yet he has assumed that these data would contribute to the elucidation of the genesis of drifting ice-fields.

Thus, it should be noted that the investigations of Gran and of subsequent explorers were confined to data on diatomaceous flora collected either from the surface of ice-floes or from their lateral cornice-shaped projections and the underside submerged in sea water. Only two of Nansen's collections represented diatom sediments gathered in the water formed by the melting young ice. The latter samples did not engage the attention of Gran.

The author of the present communication, while taking part in a series of expeditions organized by the All-Union Arctic Institute (Institute for Exploration of the North) and the Central Administration of the Northern Sea Route (Glavsevmorputj) in the ship «Lomonosov» in 1931, in the ice-breaker «Sedov» in 1934, and the ice-breaker «Sadko» in 1936 and 1937, came across several phenomena referring to the biological study of ice-floes in the Kara and the Laptev Seas. Among the most important observations which we had the opportunity of making, there were those bearing upon the solution of the question concerning the origin of ice-floes.

From general investigations it has already been known, first, that living algae are very seldom found growing on the upper surface of ice-floes (and in pools not connected with the sea); secondly, if among the polar ice one may meet «dirty» ice-floes, the latter frequently carry on their surface considerable quantities of mineral detritus which sometimes contains valves of diatoms of the most varied origin; and, thirdly and finally, observations have shown that the majority of drifting ice-floes have no visible traces of detritus and diatom valves on their surface whatsoever especially at the time they are available for investigation.

The above-mentioned facts have compelled us to look for another method of investigation and to take account of the inclusions which are found in the mass of the ice-floe, i. e. to make not only physical and chemical analyses of the ice as has been practiced heretofore, but a biological analysis too. In the very course of the expedition the collected materials proved that methodically this problem was successfully solved. There was not a single sample of ice devoid of diatoms and other frozen-in organic matter. In the course of research work extremely simple methods of taking ice samples were developed. While coordinating our investigations with the requirements of physicists and chemists, we had sample pieces of ice sawn or chipped off at definite horizons (layers) in the inside of ice. We learned by experience that for our purposes it is necessary first to take samples from no less than 3 layers: from the upper and under surfaces and from a middle layer of the ice-floes; and secondly, that it is better to adhere to one definite weight of samples and to take not less than a kilogram's weight. Mostly this proved to be quite a sufficient quantity even for very transparent ice, which is not infrequently met in the Kara and Laptev Seas. The pieces of ice obtained are first thoroughly washed with plain snow or distilled water, then each piece is left separately to melt from the surface, whereupon they are all transferred into a crystallizer or other vessel which had been cleansed with alcohol or formalin, and there they are left to melt. If the melting proceeds too slowly, a small amount of formalin is poured into the crystallizer. Thus, the development of organic matter in the water is prevented. The water derived from the melted ice (and the sediment at the bottom) is thoroughly shaken, fixed with formalin, and its volume having been measured (for quantitative purposes) it is poured into a vial. Further the process is similar to the one followed in collecting plankton by the way of settling or filtration through membrane filters. The sediment or the filtrate is kept in a small bottle labeled on its outer side. To illustrate the application of the described method for the purpose of investigation of the origin of ice-floes, I shall quote a few data from the analysis made in 1934.

I. The location of the ice-floes under observation: 1) 78°42′ N., 76°45′ E.; 2) 78°15′ N., 81°40′ E. and 3) 77°40′ N., 86°30′ E.

In the sediments derived from the melting of the majority of the ice layer samples, a detritus prevailed of light-brown colour, appearing dark-brown in mass, sometimes with a greenish tint. As to its structure, it was composed mostly of very fine mineral particles of a size 2—3 μ fused into «flakes» of

60—70—100 μ. Less frequently occurred large mineral particles and various vegetative remnants.

A biological analysis has revealed the presence of the following fresh water mass forms: *Melosira granulata*, *M. islandica* subsp. *helvetica*, *M. italica*, *Asterionella gracillima* var. *zigzagostellata*, *Fragilaria virescens*; besides, there were found in smaller quantities: *Fragilaria crotonensis*, *Tabellaria fenestrata*, *Melosira varians* and many other diatomaceae, as well as *Scenedesmus quadricauda*, *Pediastrum Boryanum* and other green algae, and remains of *Anabaena* and *Aphanizomenon* of the blue-green algae.

In some ice layers the total number of organisms reached 17 000 cells to one litre of melted water. Of the mass of diatoms found in the sample, the majority proved to be no more than empty valves, less frequently occurred diatoms which had the cells with half-destroyed contents and still less those containing well preserved chromatophores and whole cells. Among representatives of the *Melosira* species there were not less than 10—15% of the latter kind. In spite of the inadequacy and insufficient number of experiments on revival of frozen-in algae, still there were cases where the germination of auxospores was noticed in *Melosira granulata*. Already on the third day of observation, for instance, the grown auxospore was divided into two cells, whereby the latter were greatly elongated and became ready for further division. Some of the benthic diatoms met in the ice-floes continued to move after melting with considerable energy. The results of above experiments support most important biological conclusions, made by S. A. Zernov with regard to organisms frozen in fresh-water ice, on the basis of personal observations and the experiments carried out by Boldyreva, Sharmina and Shmelyova ([4],[5]). The above-mentioned composition of diatoms and other algae justifies our assertion that the studied ice-floes belong to the fresh water, fluvial ice-pack, apparently from the Yenissei river([6]), because the majority of the species are recorded in the phytoplankton of the Yenissei river, and according to recent data (as yet incomplete) also of the Ob river.

II. The location of the ice-floes: 1) 76°20′ N., 86°40′ E.; 2) 75°54′ N., 77°40′ E.

The sediment contains light-grey and light-brown detritus with particles from 2 to 60—80 μ.

In the detritus the following diatoms were detected: *Chaetoceros decipiens*, *Ch. concavicornis*, *Ch. mitra*, *Ch. furcellatus*, *Achnanthes taeniatus*, *Thalassiosira gravida*, *Thal. Nordenskiöldi*, *Thal. hyalina*, *Nitzschia frigida*, *Nitz. seriata*, numerous representatives of the *Navicula* genus and others. Among the *Peridineae* there were frequently found remnants of the genera *Peridinium* and *Ceratium*. Some of the layers of the ice-floe varied in their qualitative components. The number of organisms in some of the samples was as high as 1000 cells per litre of water. The diatoms in their majority occur in a bad condition, most frequently empty valves were observed. The algae found in the ice all belong to the marine forms; the majority are recorded or appear in the phytoplankton of the Kara Sea. Consequently, the ice-floes under investigation are of a typical sea origin.

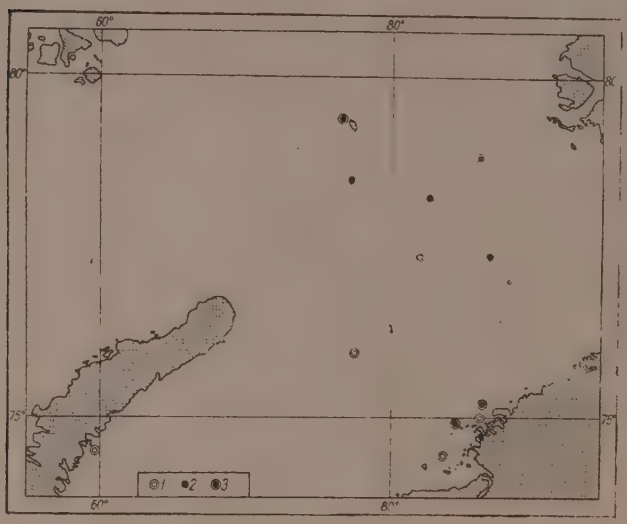
Ice one year old, encountered near the Pakhtus islands (1934) enabled us to form a preliminary idea of the occurrence of diatomaceae in the ice of this «age». The prevailing species were: *Ch. furcellatus* and *Ch. concavicornis*, of the genera *Nitzschia* and *Navicula*; also spores and cysts occurred.

III. The location of ice-floes: 1), 2) in the region 79°05′ N., 85°46′ E. and 3) to the north-west of the island Vise.

The biological analysis showed a mixed composition of diatomaceous forms. Alongside of the predominant marine forms (*Chaetoceros*, *Thalassiosira*, *Fragilaria oceanica*, *Nitzschia frigida* and others) fresh water forms were present: *Melosira granulata* and *Fragilaria crotonensis*, as well as

green algae—*Scenedesmus quadricauda*. The latter forms were well preserved and abounded only in the middle layers of the ice-floes. Thus, the ice-floes proved to be of mixed origin, and judging by the changes in the composition of marine diatoms, they were 2 years old (more than one year). The ice originated under conditions influenced by fluvial streams and afterwards drifted northwards, its further freezing having taken place in the sea. The location of such ice-floes may, possibly, indicate where the boundary of the last year's ice-fields was situated.

The figure shows a scheme of distribution of the above-described ice samples in the Kara Sea. At the same time this scheme makes it evident that among drifting sea ice ice-floes are present which, according to biological analysis, are of a different origin.



Scheme illustrating the finding of ice of different origin in the Kara Sea, from data of biological analysis (see text).
Ice: *1*—ice of marine origin; *2*—ice of fluvial origin; *3*—ice of mixt origin.

Series of other examples could be cited from the biological analysis of drifting ice-floes, land-floes, stamukhi, etc. All of them essentially contribute to establishing the characteristics of ice-fields as well as their genesis and further existence in the sea. It must be admitted that a great deal remains yet uncleared and hypothetical, since our knowledge of the sea biology and our experimental investigations in sea ice are still inadequate. The technique of taking ice samples has not been worked out either. This is a great obstacle to systematic studies of ice formations in the sea which should be conducted in the same manner of methodical sequence, in which hydrological and hydrobiological stations are operating.

By this methodical foreword the author has endeavoured to elucidate the new problems and perspectives which arise from the biological analysis of ice-floes. Joined to physico-chemical investigation, such analysis, in our opinion, will throw new light on a number of scientific and practical questions, connected with the study of drifting ice-floes (their origin, drift, etc.).

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MICROBIOLOGY

THERMOPHILE BACTERIA IN ARCTIC

By A. A. EGOROVA

(Communicated by A. A. Richter, Member of the Academy, 29. III. 1938)

Thermophiles differ from other kinds of bacteria in that they develop at higher temperatures than mesophiles. Leman and Neuman refer to thermophiles the forms for which 40—49°, 50—55° and 60—70° C are minimum, optimum and maximum temperatures respectively. These figures are far from being absolute and may be considered only as approximate temperature ranges feasible for the development of thermophiles.

While investigating the thermal waters in the North Caucasus, that is under natural conditions, we found bacteria in waters having a temperature within 80—90°. This agrees with some cases known in literature when bacteria have been found to develop at temperature above 80°.

Many authors point out that forms which require high temperatures for their development are mainly encountered in thermal waters, in substances that have suffered spontaneous heating and in the soil of the Tropics, where they have been established for instance by Nègre who investigated sand and water in the springs of Sahara.

These opinions may possibly conform to the truth in substance, but there are still others advanced on the subject. Thus, Mishustin investigated various soils of the USSR over a region stretching from Caucasus to Archangel, and found the southerly soils to contain smaller numbers of thermophiles as compared to northerly ones. The latter according to his suggestion owe their greater amount of thermophiles to manure which is not applied in the south. He arrived at the conclusion that the number of thermophiles is greater in the regions where manuring of soil is applied extensively.

I set myself the task to find out whether embryos of thermophile bacteria are encountered or not in the cold Arctic soils and sea-grounds. For that purpose I subjected to examination the specimens of sea-grounds and soils I had gathered in 1934 in desert islands of the Kara Sea while taking part, on board of the ice-breaker «Sedov», in the expedition of the Arctic Institute which had discovered these islands. The presence of bacteria in Arctic soils, if we suppose them to be brought there from some distant place of their development, would once more furnish an evidence for the possibility of microorganisms' transfer through great distances. On the other hand, we may suppose them to be relics, i. e. presume for some time past the existence of other physico-geographical conditions in the Polar basin than those which are now prevailing.

Most carefully taken samples were examined after bacteriological methods; planting was done in meat agar, broth and malt agar.

The experiments showed that thermophile bacteria are to be found in different regions of the Arctic and can develop at 60—80° C.

I discovered thermophile bacteria in the ground of Kara Sea from different sea stations (Table 1) and in the soil of the islands (Table 2), the temperature when planting being kept within 60—80°.

Table 1

№ of the stations	Date of sampling 1937	Coordinates of the stations	Depth in meters
		78°53′.8 N.	
St. 19	7.VIII	82°10′.5 E.	87
		79°57 N.	
St. 26	18.VIII	75°0′.3 E.	159
		77°07′.2 N.	
St. 49	3.IX	83°37′.5 E.	56
		77°27′.0 N.	
St. 51	4.IX	86°15′.5 E.	112
		76°02′ N.	
St. 74	19.IX	86°13′ E.	58
		75°35′ N.	
St. 82	20.IX	81°11′.5 E.	49
		76°03′.7 N.	
St. 93	23.IX	68°59′.5 E.	318

From Tables 2 and 3 it may be seen that temperature minimums feasible for the development of bacteria in the culture are lying not below 46° in the case of agar, and 36° in the case of broth. That is the reason why we have to refer the Arctic forms of thermophile bacteria isolated by us to pure thermophiles rather than to thermotolerants.

All thermophile forms of bacteria isolated from soils and sea-grounds in pure culture proved to be bacilli bearing a spore on the end, belonging to two different species.

An investigation of their physiological properties and their morphological study is in progress. As to their rôle in biological processes of the Arctic soils we have no ground to impart such a rôle to thermophile bacteria.

Table 2

Place of sampling	Meat—pepton—agar															
	80°		60°		46°		36°		30°		25°		15°		6°	
	pH		pH		pH		pH		pH		pH		pH		pH	
	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2
Isl. Dixon (soil)	+	+	+	+	±	−	−	−	−	−	−	−	−	−	−	−
Isl. of Solitude (soil)	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−
Isl. Vise (soil)	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
St. 26 (silt top monol.)	+	−	+	−	+	−	−	−	−	−	−	−	−	−	−	−
St. 26 (silt bottom monol.)	−	−	−	+	±	−	−	−	−	−	−	−	−	−	−	−

Notation: + growth; − no growth.

Table 3

Place of sampling	Meat—pepton—broth															
	80°		60°		46°		36°		30°		25°		15°		6°	
	pH		pH		pH		pH		pH		pH		pH		pH	
	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2	7.4	6.2
Isl. Dixon (Soil)	+	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−
Isl. of Solitude (Soil)	±	±	±	±	±	−	−	−	−	−	−	−	−	−	−	−
Isl. Vise (Soil)	−	−	±	±	±	±	±	±	−	−	−	−	−	−	−	−
St. 26 (silt top monol.)	±	±	±	±	±	±	±	±	−	−	−	−	−	−	−	−
St. 26 (silt bottom monol.)	±	±	±	±	−	±	±	±	−	−	−	−	−	−	−	−

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BACTERIOLOGY

BACTERIA IN THE SEAS OF THE HIGH LATITUDE ARCTIC REGIONS

By V. S. BUTKEWITSCH, Corresponding Member of the Academy

As on the earth surface in whole, so in its natural stores of water we find the existence and development of living organisms involved in the circular course of matter. We see, moreover, bacteria to play an essential part here and to link the chain of consecutive transformations. Without bacteria the cyclic course could not be maintained so as to provide nutriment for the living organisms inhabiting the earth and its stores of water.

There are two ways in which bacteria participate in this process. One of them finds its expression in the metamorphosis of matter surrounding bacteria, a metamorphosis which is due to the activity of the bacteria. The destruction and mineralization of organic compounds and the transformation of mineral substances are the effect of this activity of bacteria and lead to the formation of products which are utilized by various autotrophic organisms and principally by green vegetation. Through the activity of these organisms the products, formed as a result of the destruction and transformation caused by bacteria, become complex organic compounds and serve as food for various representatives of the animal kingdom.

The other way in which bacteria provide nutriment for the animal world is a more direct and immediate one. It refers to their growth and multiplication, i. e. the increase of their biomass. Bacteria utilize as food the solution of organic and mineral biogenic matter, scattered in the natural stores of water, and thus accumulating such matter convert it into a form that may be assimilated by living organisms feeding on bacteria. Bacteria thus serve as a medium through which the living organisms inhabiting the earth and its waters gain access to the food resources which otherwise could not be utilized by them.

The bacterial activity described by us is of particular importance in areas such as, for instance, the high latitude regions of the Arctic Ocean which are icebound all the year round and where owing the inadequate volume of light the photosynthetic activity of green organisms is either totally absent or greatly reduced. Unfortunately we have no information at our disposal concerning the presence and distribution of bacteria in those waters.

In the present communication we can only give data showing the distribution of bacteria in the waters of some regions stretching far to the north which have been investigated by the First High Latitude Expedition undertaken by «Sadko» in 1935. Acting upon our instructions, Dr. Gagarin, member of the expedition, collected materials which enabled us to ascertain the distribution of bacteria in the various layers of water in a number of stations visited by the expedition and in particular in the most northern of these stations located at latitude 83° N.

The stratification of the water at this station and at a few of the other deep-water stations in the northern section of the Kara Sea to a certain

extent resembles the stratification discovered in the Polar region at the North Pole station. We have in mind primarily the thin layer of warm Atlantic water to be found in both places at a certain depth beneath the cold, somewhat less saline Arctic waters.

The calculations made by us of bacteria contained in the waters of the most northern (№ 99) station visited by «Sadko» is given in Fig. 1 and those of the more southern station (№ 75) in Fig. 2. The figures show the vertical distribution of bacteria and also the temperature and salinity of the various layers of water. As may be seen from the figures, both these stations which have a similar stratification of the water show a similar distribution of bacteria across the strata. The investigation of the distribution of bacteria in the strata of the water of the other station in the same region showed the existence of the same relationship. Everywhere, the intermediate zone, between the upper layer of the Arctic waters and the warm Atlantic waters beneath, shows a distinct increase in the number of bacteria. The layer of Atlantic water shows in its upper part a certain decrease in the number of bacteria, but lower down the content of bacteria is more or less constant.

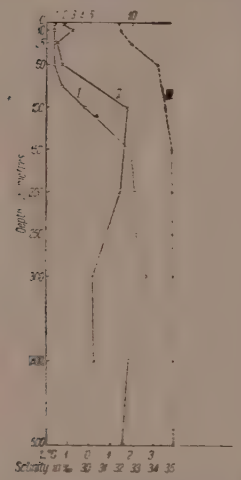

Fig. 1. Distribution of bacteria, temperature and salinity according to horizons at the station 99 (82°42′ N. and 87°03′ E., general depth 2365 m).

I—temperature °C; *II*—bacteria content per 1 cm³ of water (direct counting under microscope in thousands); *III*—salinity in ‰.

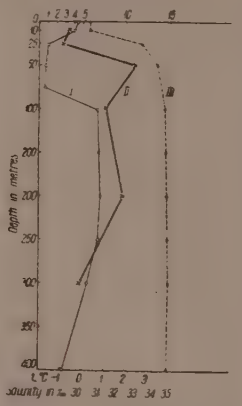

Fig. 2. Distribution of bacteria, temperature and salinity according to horizons at the station 75 (80°53′ N. and 72°14′ E., general depth 550 m).

I—temperature °C; *II*—bacteria content per 1 cm³ of water (direct counting under microscope in thousands); *III*—salinity in ‰.

Taking the size of bacteria to vary from 1 to 0.5 μ³ and accordingly the weight of 1000 million bacteria to vary from one to 0.5 mg, we get the following figures for 1 km² of the layer water which was investigated:

Station № 99, a layer of water of 400 m. . . 2500—1250 kg
» № 75 » » » » » 300 » . . . 2300—1150 »

Hence the bulk of bacteria per 1 km³ of water should weight from 3.5 tons to 7 tons.

In view of the similarity of the stratification of the water noted previously, there is reason to assume that the distribution of bacteria in the waters near the North Pole is the same as in the more southern regions of the Polar basin which were investigated. However, it is possible that in the permanently icebound regions, where the photosynthetic activity of the phytoplankton is limited, conditions prevail which in one way or another affect the development of bacteria. These conditions which materially influence the regimen of the living plankton have yet to be investigated. Now that the road to the North Pole has been opened by the valiant members of the Papanin expedition it will probably not be long before we learn more about these conditions.

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ZOOLOGY

THREE NEW DEEP-SEA FISHES FROM THE OKHOTSK SEA

By P. J. SCHMIDT

(Communicated by S. A. Zernov, Member of the Academy, 28. III. 1938)

During the scientific expedition for the investigation of our Far-Eastern Seas, organized in 1932 by the Pacific Scientific Institute of Fisheries in Vladivostok and by the Leningrad Hydrological Institute, two trawlers equipped for scientific investigations, «Gagara» and «Ara», hauled some trawls from the depths of the Okhotsk Sea and procured a series of deep-sea fishes. Although the collection proved to be rather scanty, investigation showed it to contain some new species. In the present paper a preliminary description of three of them including a representative of a new genus is given. A more full and detailed description with measurements and illustrations will be given in a future paper «Fishes of the Okhotsk Sea», which I am preparing for the press.

Fam. ZOARCIDAE

Bothrocarichthys gen. nov.

Body elongated, compressed. Head small with short blunt snout and broad interorbital space. Many rows of large pores on head. Teeth in jaws, vomer and palatines; large canine-like teeth in jaws. Body covered with cycloid scales. Vertical fins united; ventral fins absent; pectoral fins long, nearly riching to anus. Gill-membranes united to the broad isthmus. Pseudobranchiae and gill-slit behind the fourth gill-arch present. Gill-rays 6. Lateral line present.

This genus is closely related with *Bothrocaropsis* Garman, from which it differs by the presence of the lateral line, by the canine-like teeth and by the shape of the head and the large pores on the latter.

1. *Bothrocarichthys microcephalus* sp. n.

D 84, *A* 72, *P* 10. Body compressed, elongated, tapering to a narrow and slender tail; its depth about 8.0 in total length. The upper profile of the head somewhat deepened above the eyes. Head small, with a blunt, rounded snout, 6.4 in total length. Eye oval, small, 5.6 in head; interorbital space broad and flat, 2.9 in head; snout 3.2 in head. Mouth large,

oblique: maxillary reaching the vertical of the posterior margin of eye. Lower jaw shorter than the upper. Teeth strong, conical, slightly curved and directed backward; anteriorly two rows of teeth, posteriorly one row; one pair of large canine-like teeth in the upper and two in the lower jaw; 3—4 teeth on the anterior part of the vomer and one row of teeth on palatine-bones. One pair of nasal tubes. A row of 6 large pores below eye, a vertical row of 3 pores behind them, 6 pores on the lower surface of the lower jaw, 3 large pores above opercle and 3 pores on the margin of preopercle; no other pores on the head. Nape, occiput, opercles and preopercles scaly, anterior part of the head naked. Gill-membranes attached to the isthmus: the latter is as wide or wider than the diameter of eye. Gill-rackers short, flat, spinous, 3+10 on the first arch. Pseudobranchiae developed, a slit behind last gill-arch present.

Dorsal fin beginning above the middle of pectoral, anal fin immediately behind vent. Dorsal and anal low; the height of the former is about equal to the width of the interorbital space. Both vertical fins connected to the top with caudal, forming a pointed tail. Body and fin-membranes scaly, only the margins of the latter naked. Scales small, cycloid, imbedded in the skin, forming pigmentless round spots on the skin, covered with small points. Pectoral fins long, about $^6/_7$ of the length of head. Lateral line running from above the gill-opening to the base of tail; it is of about 50 pores.

Colour in alcohol brownish-grey, darker on the dorsal side; head blackish, especially snout and lips. Vertical fins grey, blackish to the tail. Mouth-, gill- and body-cavities white.

Length of body 359.0—397.0 mm.

5 specimens found off west coast of Kamchatka, 58°21′ N., 153°30′ E., 70—190 m depth, by the trawler «Plastoon». The fish seems to be semi-bathybic, living on the continental slope.

Fam. BATHYLAGIDAE

2. *Bathylagus ochotensis* sp. n.

D 10. *A* 15. Body compressed, slender, its depth 5—7 in length without caudal. Head 4.5; eye 2.75 in head; snout 2.0 in eye. Upper profile of head nearly straight. Interorbital space broad, flat; its width, including thin membranous plates overarching the orbits, about equal to diameter of eye; on the interorbital space two longitudinal ridges, somewhat diverging posteriorly, with a median ridge between them in the widened part, beginning on the occiput; this last ridge is widened posteriorly and shows a small round whitish spot seen through the transparent bone. Mouth small, oblique; length of maxillary 2.5 in eye; lips membranaceous, overlapping the mouth. Teeth small and scarce in the upper jaw; in the lower jaw in the mouth-angles only; teeth on the vomer. Orbital cavities with adipose tissue before the eye. Opercles with a notch on the posterior margin: the upper end of gill-opening nearly on the level of centre of eye; radiating striation in the lower part of opercle, ridges absent.

Dorsal fin nearer to the adipose fin than to tip of snout; its base somewhat longer than the eye diameter, 2.4 in head. Base of anal fin 1.8 in head. Adipose fin long and narrow, not reaching rudimentary rays of caudal fin. Distance from end of anal to base of caudal equals distance from tip of snout to posterior margin of eye. Scales, judging from the scars, in about 40 rows.

Colour brown, head blue-black, silvery. Length of the single specimen 95.0 mm.

One only specimen found in the Okhotsk Sea, off east coast of Sakhalin Island 55°18′ 30″ N., 146°39′ E., 592 m depth, ground ooze, by the trawler «Gagara».

This species differs from all the pacific species of *Bathylagus* known (*B. pacificus* Gilbert, *B. borealis* Gilbert and *B. milleri* Jordan a. Gilbert) by its broad and flat interorbital space with ridges. It seems to approach the nearest to *B. borealis* Gilbert, but the head is shorter, the eye smaller, the interorbital space broader and the depth of body less. The notch on the posterior margin of the opercle seems also to be peculiar to this species only.

Fam. GADIDAE

3. *Laemonema longipes* sp. n.

D VI, 50, *A* 46, *P* 17, *V* 2. Body elongate, compressed, tapering to very slender posteriorly; body cavity about $^1/_5$ of the length of body without caudal. Head of medium size, its depth somewhat more than its width; interorbital space and occiput flat. Eye medium-sized, its diameter 4.6 in head, shorter than rounded snout which is 4.0 in head. Maxillary reaching to vertical of the centre of eye. Mouth oblique; lower jaw somewhat longer than the upper, with a protruding knob. Jaws with small conical teeth in 2—3 rows; a toothless space in the median line of the upper jaw; a row of teeth on the head of the vomer. Head scaly posteriorly, but anterior part of the snout and jaws naked. Small pores above the maxillaries and three pairs of pores on the snout and on the interorbital space. Nasal pores large without tubes. Gill-openings wide, continued forward under the throat and ending anteriorly of the mouth-edges. Gill-membranes free from the isthmus. 6 gill-rays. On the first gill-arch 5—7 gill-rackers above and 19—20 below, they are long and slender. A slit behind last gill-arch; pseudobranchiae absent. No barbel.

Body scaly; scales imbricated, larger than in *Laemonema gracillipes* Garm.; about 130—150 transversal rows of scales along the lateral line to base of caudal; 10 rows of scales above and 30 rows below lateral line. The latter running nearly in a straight line from above the gill-opening to base of caudal, consists of a subcutaneous channel, covered by scales and opening only with about 30 pores, placed at a distance of 5—6 scales one from another, difficult to count in the posterior part of the line.

First dorsal fin beginning a little behind the vertical of the pectoral base, short and low, scaly on the base; its first ray the longest, equalling the length of snout, or somewhat longer. The distance between the first and the second dorsal fins equals half diameter of eye. Second dorsal higher than the first, scaly to $^2/_3$ of its height. Anal fin lower than the second dorsal. Caudal fin narrow, truncated, not joint with either of the two vertical fins. Pectoral fin narrow, attenuated to the tip, as long as the head, or a little shorter. Ventral fin of two separate rays only, no rudimentary rays present; the rays very long, cirrus-like, reaching by their tips nearly to the middle of the body length; both rays are of the same length.

Colour brownish; each scale with brown stellate pigment cells; head, belly and sides of body below the pectoral fin silvery. Mouth-cavity, gill-cavity and fins blackish.

Length of body 118.0—502.0 mm.

Two specimens found in the same region of the Okhotsk Sea, 55°42′ N., 143°34′ E., 542 m, and 55°13′ 30″ N., 146°34′ E., 592 m, by the trawlers «Ara» and «Gagara», and two specimens catched off west coast of Kamchatka by the trawler «Plastoon».

The species is in its general features very near to *Laemonema gracillipes* Garman, but differs by larger scales, smaller eyes, longer pectoral and ventral fins and a smaller number of rays in the second dorsal, in the anal and the pectoral fins*.

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* Garman (Mem. Mus. Comp. Zool., XXVI, 1899, p. 187, pl. XVII, fig. 1) attributes to *Laemonema gracillipes* a fin formula *D* VI, 63—68, but on his figure the first dorsal fin has only 5 rays.

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